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Forthcoming Events.

JUNE 4-5.

British Empire Mining and Metallurgical Conference.—At Wembley.

JUNE 4 to 6.

Institute of British Foundrymen. — Annual Convention at Newcastle.

JUNE 19 to 28.

International Foundry Trades Exhibition.—At Bingley Hall, Birmingham.

JUNE 25 to 27.

Foundry Technical Congress.—Bingley Hall, Birmingham.

THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN AND THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION.

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The Mystery of Cast Iron.

It is now quite clear that chemical composition, as normally expressed, *per se* is often quite unable to explain the difference in the properties of two identical (for all practical purposes) cast irons, and it is interesting to examine the theories put forward by various schools of thought and to indicate the nature of the research necessary to prove the implied assumptions.

Primarily, the practical man overcomes the difficulty by ascribing any enhanced properties to "body," "inherent properties," or "guts" in the pig-iron used. His ground being incapable of scientific explanation without elaboration is likewise incapable of refutation.

A theory held by many is based on the presence of good property-giving graphite in the pig-iron, which persists even after melting in the cupola. Yet an iron-carbon equilibrium diagram seems to indicate that the graphite of normal percentages is in solution at melting point. Some experimental proof is available where cast-iron has been quenched from the liquid state and the resultant sample has been quite free from graphite. Yet skeleton pig-iron has been seen where the iron has melted away leaving a sponge of coarse graphite. Then, too, kishy pig-iron has recently involved a £300 loss to a foundry making castings which have to withstand hydraulic pressure-testing. Logically examined, therefore, there must be a third element or force which causes or prevents the solution of graphite in cast iron, or its re-precipitation in the same form. Another thought on this subject is that any undissolved graphitic carbon should float on the liquid and be capable of being skimmed off. This is observed constantly when making high-silicon, acid-resisting cast iron. Surely, the research to be carried out is a series of quenching tests from the liquid state on the many varieties of alloys which can be classed as cast-iron, using increasing weights of samples so as to receive an appreciation of mass effect.

A more modern theory is that which has been hinted at by Mr. Kent Smith, and relates to the influence of nitrogen. Here are introduced a number of complex questions. Primarily, hot-blast furnaces have a greater chance of nitrogenising cast-iron, and generally speaking cold-blast iron is the stronger material; but the graphitic theory can also explain this phenomenon. Again, electric steel made under high voltage, that is long arc, conditions is subject to a state of affairs which can be associated with the fixation of nitrogen. Practical experience has shown that low-voltage and under-powered furnaces make the best steel. Thus a fair amount of empirical evidence is available to show that the action of combined nitrogen is detrimental to steel, and perhaps one can reasonably assume, for the ferrite in cast iron, but is it possible to conceive that it has any effect on the graphitic structure of cast iron? Before any conclusions can be drawn, a reliable method must be evolved for the estimation of the nitrogen content of ferrous alloys, and it is surprising that after four or five decades of the chemical analysis of these materials, no real solution of the difficulty has yet been found.

Lastly, some metallurgists hint that, owing to the incompleteness of the expressed analysis of cast iron, many elements may be present in small quantities which may profoundly alter the mechanical characteristics of the alloy. There may again be a connecting link between this theory and the nitrogen theory. In fact, some of Mr. Kent Smith's work points to the existence of such a connection. To prove this theory, a long and arduous task awaits the investigator, and his research would involve the determination of the influence of small quantities of various elements upon many varieties of cast iron.

There may be other theories to account for complex behaviour of two cast irons of similar composition as normally expressed, and their enunciation, providing that they are logically enunciated, would do much to clear up the present mystery.

Correspondence.

[*We accept no responsibility for the statements made or the opinions expressed by our correspondents.*]

Sand and Coke.

To the Editor of The Foundry Trade Journal.

Sir,—In connection with my recent letter appearing in your issue of April 10, regarding coke consumption to the ton of iron melted, and the amount of new sand to the castings made, and in consideration of the replies received through the medium of your valued paper, I would take this opportunity of supplying some information which may assist "F. W. R." and "Disce-Dosce."

Sand.—The point here on which I desire information is what percentage of new sand should be used for facing sand mixtures and what relation should the weight of new sand bear to the weight of castings produced. The plant employed for mixing is a "Herbert Centrifugal" and an electric riddle (no milling of sand is done).

The type of castings produced must have a good finish, and in a large number of cases are machined all over so that solidity is also a criterion. It is difficult to state the exact type of castings, as the foundry in question produces general castings, such as castings for machine tools, induction motors, ships' engines, tank plates and general.

The cupola producing most of the metal is lined to 32 in. dia. There are two rows of tuyeres, four in each row, giving a total tuyere area of 148 sq. in. The blast is supplied by a Keith-Blackman fan, and the cut-off arrangement gives a static pressure of 10 ozs. at the commencement of a blow. Unfortunately no reliable means of measuring the volume is available, as the fan is in such close proximity to the furnace, there being no straight parallel length of blast-pipe available for volume measurement.

Charges.—Charges consist of 10 cwts. of iron (weighed) and 1 cwt. of coke. The scrap, which forms 25 per cent. of the charge, is rather of a heavy nature, 35 per cent. is pig and the remainder shop returns, which are fairly light.

The metal is very fluid as tapped, but being fairly low in silicon (1.6 per cent.) and phosphorus (0.5 per cent.) must carry a fair degree of superheat, as it must be carried some distance in a number of cases before casting. Between 5 and 6 tons are average melts. It is usual to count in the coke bed when figuring the melting ratio.

I trust that the particulars which I now give will enable my foundry friends to give me some information on the points desired which, I can assure them, will be much appreciated.

I am,

Yours, etc.,

G. Findlay.

8, Buchanan Terrace, Paisley.

Foundry Queries.

"Cold Metal."

I have a 24-in. dia. inside diameter cupola with two tuyeres each 6½ in. dia., made from a boiler tube, with wind belt 3 ft. 8 in. dia. by 3 ft. deep by 4 in. wide. The blast is supplied by a direct-coupled K-B fan, 8 in. outlet, which was made to supply 2,000 cub. ft. of air at 12-in. water gauge per min. As this is alternating current-driven I cannot alter the speed. To get the desired amount of air I have connected a 4½-in. dia. pipe from the fan to the air belt. The charges are 5 cwt. of iron, 60 lbs. of coke and 10 lbs. limestone, and the best results are obtained with a coke bed 2 ft. 8 in. above the tuyeres. I would appreciate any advice to make the metal hotter.—J. R. R., Bolton.

Locomotive Cylinders.

The remarks made by "Rerum Cognoscere Causas" are very interesting, but ironfounders must differentiate between locomotive and motor cylinder castings. The ultimate requirements are so very different.

The research in America has been carried out by the Bureau of Standards, and "Rerum Cognoscere Causas" should obtain a copy of their report, which is now available. This report entirely supports the opinions given in my previous communication. Journal 19, American Foundrymen's Association, also gives confirmatory details. "Rerum Cognoscere Causas" evidently has misread Prof. Campion; he clearly states that semi-steel, to be properly made, should be air-furnace melted, which, of course, is well known. Hence the conclusions of the Bureau of Standards in this matter.—Disce-Dosce.

Porous Gunmetal Castings.

The four causes stated will produce, as "Worried Brass Moulder" assumes, direct porosity in metal or castings, and without a more detailed information it is not possible to state a definite or correct method to overcome the defective results.

It is not an uncommon error for non-ferrous foundrymen to take an insufficient amount of interest necessary in the melting of the metals or alloys. From my own experience I conclude that there are more scrap castings produced from the melting department due to careless control than any other part of the foundry. Referring to mixture bought to specification from a well-known firm, from which I gather is meant reliable manufacturers, I cannot see any reason for complaint, having used ingots of metal ready mixed to specification in all classes of compositions which have withstood any normal test.

In regard to the yellow scum forming round the top of the crucible, you do not state whether this scum is in the form of a slag, fluid mass, or in powder form. If the following method is followed closely it is thought that the defective results will be eliminated.

Assuming that the pot has been charged with metal, it is good practice to throw on top a small handful of common salt (NaCl), melt quickly, and err on hot side. When metal is sufficient hot lift from furnace, stir thoroughly. Add about half-a-pound of 15 per cent. phosphor copper to 100 pounds of metal, then stir again carefully; skim off and cast at once.

Care must be taken that the sand is well mixed and not too damp or wet. The sand must not be rammed too hard, and must be vented freely. In each box cast a test bar thicker in section than the castings and if possible gated from the same runner as the castings. Each test can be marked 1, 2, 3 and so on to the number of boxes that will run out or empty the crucible.

Number 1 is cast the first, so this will be the hottest metal which on machining will show up any defects if any; also, when broken, the grain structure can be examined. This method will give a rule-of-thumb temperature control if carried out to the last test bar.—G. C. Swift.

Catalogues Received.

Oil Cans.—We have received from Messrs. Joseph Kay & Sons, Limited, of Lock Works, Leeds, their new price list. Some half-dozen new types have been included in this new edition.

The Glen Irvine Iron & Steel Company, Limited, of 20 St. James's Square, London, S.W.1, who have works at Richborough, Kent, and Trafford Park, Manchester, are placing on the market a series of special pig-irons for malleable-iron founders.

We regret to announce the death, at Bournemouth last Tuesday, of Mr. W. C. Gould, an old and respected member of the Institute of British Foundrymen, and father of Mr. L. P. Gould, the Branch President of the Wales and Monmouth section of the Institute. Mr. Gould was a director of Messrs. Gould's Foundries, Limited, of Vulcan Foundry, Eastmoors, Barry Foundry, Barry Docks, Cardiff, and Tredegar Foundry, Newport.

The name of the Cambridge & Paul Instrument Company, Limited, has been changed by consent of the Board of Trade to:—The Cambridge Instrument Company, Limited. The head office and showrooms of the company will continue to be at 45, Grosvenor Place, S.W.1, and the business of the company will be carried on exactly as in the past.

On the Working Slags in Ferrous Processes.*

By J. E. Fletcher, M.I.Mech.E.

All metallurgists are now convinced of the fundamental importance of the slag function in ferrous processes, and in the present Paper the author can only wish to outline these functions.

The whole subject offers a wide field for research, though at the outset one is compelled to assert that there is extreme difficulty in obtaining in the laboratory parallel results to those which hold in actual practice. The effects of time and mass are important, and it must be seen that synthetically prepared slags, formed from mixtures of the raw constituents, when fused together in small samples, present often fundamental differences, constitutionally, from slags which have formed in the heating zones of large furnaces where the exchanges occur in presence of phenomena which cannot easily be reproduced in the laboratory.

When the natural slags reach the hearth they meet there the ash slags and lime, though possibly in the descent through the fusion zone (boshes) contact with lime and magnesia in the added fluxes limestone or dolomite takes place and leads to an alteration in the slag composition.

In Table I two typical coke ash analyses are included, showing the very varied types of ash slags, the first a very viscous and the second a liquid free-running variety.

When the gangue, coke ash and lime are mutually fused in the hearth they have an altered composition as given in Table II. Here three representative slags from Cleveland, Northampton and Hematite burdens respectively show the altered composition.

TABLE I.—*Analysis of Iron Ores and their Softening Temperatures.*

		Gangue.						
	FeO & Fe_2O_3	SiO_2	Al_2O_3	P_2O_5	MgO	CaO	MnO	Softening temp. in deg. C.
Lincolnshire ..	59.7	44.5	13.7	2.0	2.5	33.6	1.5	1355
Scotch ..	65.8	49.5	27.7	2.5	5.5	10.5	1.4	1445
Cleveland ..	50.9	39.5	28.7	3.2	15.8	10.9	0.5	1405
Hematite ..	87.0	73.0	9.5	—	1.5	9.2	0.9	1375
Northampton ..	65.5	59.3	20.3	1.5	12.3	1.8	0.7	1350
Flue Cinder ..	70.5	28.0	—	0.5	—	—	1.0 S	1250
Analyses of ..	30.0	54.0	2.63	0.36	1.75	9.70	1.49	1350
Coke ash ..	12.3	44.9	39.00	0.70	—	—	0.80	1400

Blast Furnace Slags.

In the smelting of ores by means of coke or coal and air the earthy matter or gangue is itself a cooled slag, as is the ash of the coal or coke.

It is useful and indeed essential in studying the mechanism of slag formation in the hearth of the blast furnace to consider the various types of slags which first form or fuse as the several ores in the charge or burden descend into the fusion zone. Each ore has its own natural gangue slag, and fuses in turn in accordance with its fusion temperature, and descends more or less rapidly in proportion to its viscosity.

It is now recognised that the alloying of the iron in the blast-furnace hearth takes place by reactions through the slag.

The carburised metal which primarily falls into the hearth is approximately of eutectic composition, though, owing to temperature influence and to variations in time of contact between the coke, reducing gases (CO), and the iron reduced from the ores, it may be hypo- or hyper-eutectic, *i.e.*, under or over the carbon content of the pure C.Fe eutectic (4.3 per cent C.).

The alloying action takes place by means of reactions between the carbon in the liquid metal,

TABLE II.—*Compositions of Typical Slags.*

	Slag per 100 lbs. pig-iron.	Silicon in pig-iron.	SiO_2	CaO MgO FeO	Al_2O_3	CaS TiO_2 etc.	SiO_2 (active).
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Cleveland ..	122.6	0.0	33.1	37.0	25.0	taken	10.6
	120.5	1.0	31.8	38.1	26.1	at 4.0	9.3
	118.3	2.0	30.6	39.1	26.3		7.6
	116.5	3.0	29.5	44.0	26.5		5.6
Northampton ..	140.1	0.0	36.5	42.1	17.4	4.0	11.7
	138.0	1.0	35.3	43.0	17.7		10.1
	135.8	2.0	34.5	43.5	18.0		9.0
	133.7	3.0	33.3	44.5	18.2		7.2
Hematite	49.5	0.0	38.5	42.8	14.7	4.0	13.2
	48.9	1.0	35.7	44.9	15.4		9.2
	45.2	2.0	32.6	47.2	16.2		4.9
	43.2	3.0	29.5	49.3	17.2		0.8

Table I gives comparative analyses of five different ores and of an artificial slag (flue cinder) produced in the puddling furnace, and which is often used in blast-furnace burdens, together with the approximate softening temperatures, which may be 100 or 200 deg. C. lower than the free running temperatures.

These analyses indicate the varied characteristics of the slags which first form. From Field's researches on the viscosity of blast-furnace slags it has been proved that the slags richest in silica are generally the most viscous, except in the case of high alumina contents.

and the silicon, phosphorus and manganese in the primary slags, thus typically:—

$$2\ Fe_3C + SiO_2 = Fe + Fe_2Si + 2CO$$

$$6\ Fe_3C + 3\ MnO = 9\ Fe + Mn_3C + 3\ Fe_3C + 3\ CO$$

$$3\ Fe_3C + 4\ CaO\ P_2O_5 = 3\ Fe + 2\ Fe_3P + 2\ FeO + 4\ CaO + 3\ CO$$

and

$$2\ FeO + 2\ C = 2\ CO + 2\ Fe$$

The entrance of Si Mn and P into the pig-iron is thus seen to be an exchange between the oxides of silicon, manganese and phosphorus and carbide of iron.

Silicide of iron Fe_2Si (or FeSi + Fe), manganese carbide Mn_3C, and iron phosphide Fe_3P, are the forms in which the elements Si, Mn and P are

* A Paper presented to the Birmingham Branch of the Institute of British Foundrymen, Mr. J. B. Johnson presiding.

finally found in the solid pig-iron. As indicating the manner in which (during the alloying of silicon with the iron) the slag composition progressively changes Table II has been prepared, the analyses being given of the hypothetical primary slags before silicon begins to alloy with the iron.

The author, in a Paper read before the Iron and Steel Institute in 1921 on this subject, sought to show that working slags tend towards an inert condition wherein the acid and basic oxygen are equalised. There is strong evidence that in blast-furnace slag the CaO. MgO silicate forming at the hearth temperature is the stable ortho-silicate 2 (CaO. MgO) SiO_2 in which is dissolved alumina—probably as aluminate of lime of type Al_2O_3 $(CaO)_n$ —and free silica. If the silicate and

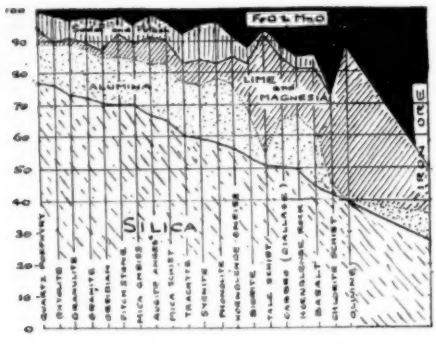

FIG. 1.—CHEMICAL COMPOSITION OF IGNEOUS ROCKS ANALOGY WITH FURNACE SLAGS.

aluminate of lime are stable, then it follows that the free SiO_2 is the source from which the iron in the hearth draws its silicon. It is somewhat remarkable and important to observe that the liquid composition of a normal slag of analysis:—CaO, 45.5; SiO_2, 32.3; Al_2O_3, 18.4, and CaS, etc., 3.8 per cent.

This may be expressed as: 3 CaO. Al_2O_3 (stable and inert), 2 parts, 48.6 per cent.; 2 CaO. MgO. SiO_2 (stable and inert), 1 part, 23.5 per cent.; Free Silica, 24.1 per cent.; CaS, etc., 3.8 per cent. Most blast-furnace slags can be thus estimated. Where the Al_2O_3 exceeds 20 per cent., it would appear that the stable and inert tri-calcic

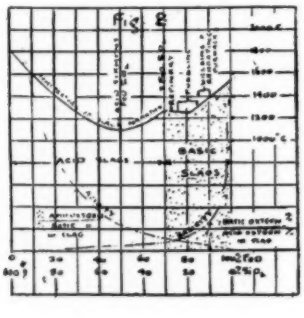

FIG. 2.—RANGE OF FERROUS SILICATE SLAGS.

aluminate 3 CaO. Al_2O_3 is not reached, a lower acid constituent being formed. The point here raised is of interest, and though definite proof is inaccessible, a great deal of recent research on refractories and slags has shown that the first constituent to form are the meta-stable silicates and aluminates, these being generally fusible at a much lower temperature than the ortho-silicates and aluminates.

These latter, on cooling sufficiently slowly, decompose, leaving in the cold slags, the meta-silicates or aluminates. Thus in blast-furnace slags a rapidly cooled sample will often show the presence of fayalite, rhodonite, the ortho-silicate of iron, manganese and lime, and the ortho-aluminates of lime and magnesia, though these last are but rarely seen and then only in traces. A slowly cooled sample is free from the ortho-silicates and aluminates the decompositive products, the meta-forms (RO. SiO_2) and (RO. Al_2O_3) or (2 RO. Al_2O_3) being dominant.

Mechanism of the Formation of Slags.

The author has gradually come to the conclusion that the mechanism of the formation of the slags which arrive from the admixture of earths, as is the case in the blast furnace and cupola, is as follows:—

(1) The free silicon, lime and magnesia, with the natural silicates and aluminates found in the ores, sands and coke ash, and eroded from the furnace linings or as oxidation products of the molten metal, when fused, form equilibrated products dependent on the temperature.

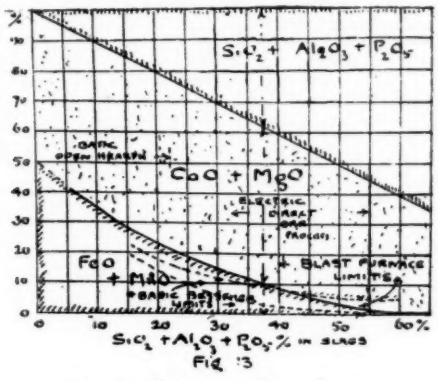

FIG. 3.—RANGE OF BASIC SLAGS.

(2) These first products are the meta forms (RO. SiO_2), (RO. Al_2O_3), or generally the acid slags whose index ratio $\frac{\text{Basic oxygen}}{\text{Acid oxygen}}$ per cent. is greater than unity.

(3) If the temperature of the furnace hearth is greater than that necessary for the formation of the acid slags, these gradually absorb further basic RO oxides until at sufficiently high temperature, the ortho-silicate and aluminate form. These are inert and do not give up their silicon, iron, manganese to the metal.

(4) If the composition of the slags thus formed is entirely that of a mixture of the stable silicates and aluminates, the slag is inert, but generally there is present an excess of one or more constituents, such as SiO_2, MnO and FeO, which, being actively free, alloy with the metal in the hearth.

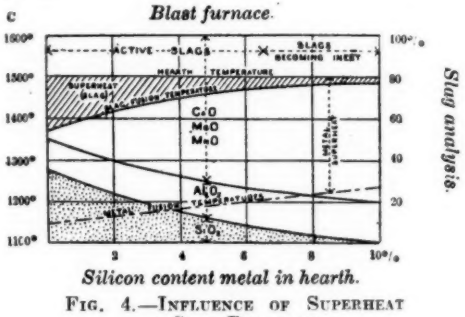

FIG. 4.—INFLUENCE OF SUPERHEAT ON SLAG REACTIONS.

(5) When the hearth metal is superheated to temperatures far in excess of its fusion point, and especially when the slags are similarly superheated, the alloying actions are speeded up.

(6) When the atmospheric conditions in which the slag and metal reactions occur are oxygenic, the hearth metal is oxidised, the basic oxides of iron and manganese being robbed from the bath: thus promoting the attainment of the inert conditions.

(7) If the temperature be further increased beyond that of the inert slag formation, and the atmospheric conditions are oxygenic, the tendency is in the direction of drastic hearth-metal oxidation, the metal becoming rich in gases and oxide inclusions.

(8) As perfect diffusion of the various silicates, aluminates and other oxides is impossible in the

mass conditions of large furnaces, it is possible that heterogeneous actions of the types enumerated occur.

The blast furnace type of slags and their form of development (constitutional) have already been described.

Cupola Slags.

In re-melting processes, that of the cupola is the first of importance. Here the temperatures

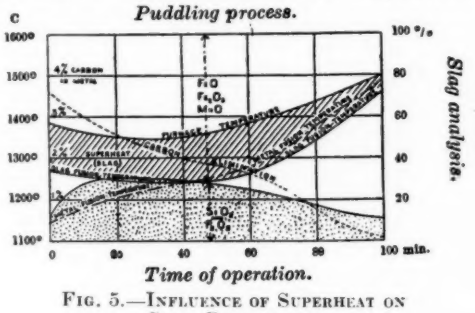

FIG. 5.—INFLUENCE OF SUPERHEAT ON SLAG REACTIONS.

are lower than in the tuyere zone of the blast furnace, and though the slags are of the same family type, the absence of sufficient lime to meet the silica demands leads to iron oxidation unless there is enough iron oxide in the charge (in the coke ash and scrap rust) to serve.

Here the tendency is towards the meta-silicate type of slag, and a representative composition is given illustrative of the fusion zone activity (see Table III and also Fig. 1).

TABLE III.—*Composition of Cupola Slags as Meta-Silicate type.*

	A.	B.	C.
SiO_2	55.0	42.0	35.0
MgO & CaO	15.0	36.0	45.0
FeO & MnO	22.0	10.0	5.0
CaS, etc.	1·0	2.0	3.0
Al_2O_3	7.0	10.0	12.0

Supposing the meta-silicates and aluminates to be of the types (FeO. MnO) SiO_2, CaO, SiO_2, 2 CaO, Al_2O_3, the constitutional liquid composition of the slags may be thus stated:—

TABLE IV.—*Composition of Slags more Constitutionally Expressed.*

	A.	B.
	Per cent.	Per cent.
(FeO MnO) SiO_2	40.3	18.3
(CaO MgO) SiO_2	15.2	52.0
2CaO Al_2O_3	14.7	21.0
Free SiO_2	28.8	6.7
CaS, etc.	1.0	2.0

By more suitable limestone additions the slag may be made less silicious, lower in iron content and more fusible. Slag B is representative of the function of limestone in reducing the free silica and ferrous silicate constituents, thereby increasing the fluidity and lowering the temperature of slag fusion. In some cases, where very hot working is practised, there is little doubt that the inert condition is sometimes arrived at as in slag C, which, though very high, limestone addition has approached the blast-furnace type. There is the possibility in such a case that the inert condition of the RO silicates and aluminates having been reached, the tendency is towards excessive oxidation in the tuyere zone. This view is supported by the fact that when too much limestone is added, the slags become very refractory, and the metal loses much silicon, iron and manganese. The slag resulting from too much limestone addition adjusts its equilibrium composi-

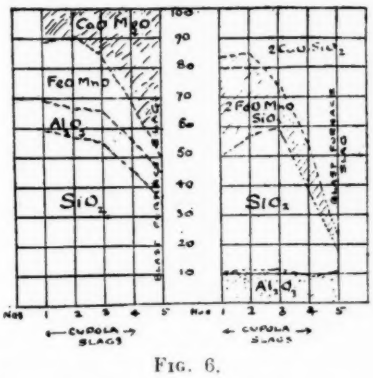

FIG. 6.

tion corresponding to the fusion zone temperature by robbing the metal of iron, silicon and manganese.

Refinery Slags.

An interesting sidelight is thrown on the problem of iron remelting slags by the composition of the slags produced in remelting and partially refining cast iron. The melting was obtained in an open hearth, the iron being covered with coke and blown into by a series of air blast tuyeres. The "running-out" slags, as they are called, have the following representative analysis:—FeO, MnO = 67.0; SiO_2 = 26.0, and Al_2O_3, etc. = 7.0 per cent. Here no limestone was used as a rule because of the desire to use the resulting slag in other iron work operations.

A grey iron would become white through loss of silicon which passes into the slag along with certain oxidised iron as FeO. The resulting slag was therefore formed from the coke or coal ash, oxidised iron and silicon from the remelted metal.

Here at the low temperatures practised the silicates of iron and manganese are of the meta-stable order containing about 55 per cent. FeO, MnO and 45 per cent. SiO_2, in which excess FeO (or Fe_2O_3) is dissolved. The analysis and fluid constituency are given in Table V.

If refined at high temperature, the stable constituents are probably present as shown at (A).

TABLE V.—*Composition of Refinery Slags.*

				A.			B.			
FeO	SiO_2	MnO	P_2O_5	2FeO MnO SiO_2	5FeO P_2O_5	Free FeO	FeO SiO_2	4FeO P_2O_5	Free FeO	Free SiO_2
65.0	25.0	2.0	2.5	85.0	7.4	2.1 SiO_2	55.0	6.5	33.0	—
55.0	33.3	3.0	2.0	82.3	5.9	5.1	73.3	5.2	14.8	—

TABLE VI.—*Composition of Bessemer Converter Slags.*

	FeO+MnO	SiO_2	Al_2O_3	CaO, etc.	2FeO / MnO } SiO_2	Free SiO_2	Al_2O_3 CaO, etc.
A.	53.9	43.8	7.5	1.0	74.8	21.9	about 3.0
B.	50.6	45.9	about 2.2	about 1.0	71.7	24.8	
C.	58.5	39·0			82.9	14.6	
D.	57 3	37.6			81.3	13.6	

Bessemer Converter Slags.

In the acid Bessemer process the oxidation of, say, 1.0 per cent. Si and 1.8 per cent. Mn, from the molten-charged metal would be represented in a slag of estimated analysis and constituency (Fig. 7).

Actually the analysis of a series of slags during a blow are given at B, C, and D. It is often found that the oxidation of the iron results in the two oxides FeO and Fe_2O_3, which are found in definitely related content, dependent upon temperature conditions, and on the presence of available oxygen in excess of the amount necessary for the formation of ferrous oxide.

A wide survey of slags containing the two oxides FeO and Fe_2O_3 suggests the possibility of the formation (in high temperature furnaces working under strongly oxidising conditions) of iron oxide slags of composition $FeO_n\ Fe_2O_3$ type, the Fe_2O_3 acting as acid to the basic FeO. Oxide slags have been recovered from high temperature ingot soaking pits of the neutral composition corresponding to the form $3FeO.\ Fe_2O_3$;

$$\left(\begin{matrix}\text{FeO}=57.5\text{ per cent.}\\ \text{Fe}_2\text{O}_3=42.5\text{ per cent.}\end{matrix}\right)$$

Table VI gives the trend of the progressive slag changes during the blowing of a charge of acid Bessemer steel.

Here the slags in the liquid condition contain the ortho-silicate $2(FeO.\ MnO)\ SiO_2$, in which excess silica is dissolved. The cooled slag is of the RO SiO_2 type. Microscopic examination of quickly-cooled slag reveals the presence of fayalite and rhodonite $2FeO\ SiO_2$ and $2MnO.SiO_2$, and a glassy constituent mainly silica.

Whitely has described the mechanism of the formation of the ferrous silicates $2FeO.SiO_2$ and $FeO.SiO_2$, the former being the stable form at high temperatures above 1,300 deg. C., the latter a meta stable decomposition product formed on cooling slowly the stable form. It may be expressed as $(2FeO)\ SiO_2 + SiO_2 = 2(FeO.SiO_2)$.

Table VII. similarly gives the progress of an acid Bessemer blow in a converter of the Tropenas or side blown type (Fig. 7).

Table VII.—*Composition of Sideblown Converter Slags.*

FeO + MnO	SiO_2	Al_2O_3 CaO, etc.	2 (FeO MnO) SiO_2	Free SiO_2	Al_2O_3 CaO, etc.
58.7	36.7	4.6	83.2	12.2	4.6
52.3	42.5	5.2	74.5	20.3	5.2
54.2	50.9	4.9	77.0	28.1	4.9
43.8	51.0	5.2	62.2	32.6	5.2
33.9	61.3	4.8	48·0	47.3	4.8

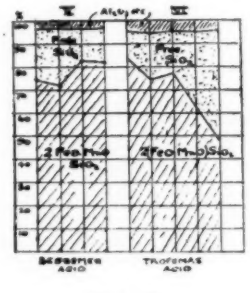

Fig. 7.

It is interesting to note the fact that the slags in surface-blown converters become increasingly silicious whereas in the through-blown converters of Bessemer type the opposite effect occurs. In the latter case the increase of iron oxide, brought about by excessive oxidation of the metal, coincides with the fall in the silica content.

The gradual progress towards the inert condition is evident. Certain lining erosion is reflected in the slag by Al_2O_3 and excess SiO_2 content.

Basic Bessemer.

In the basic Bessemer process the addition of lime and the presence of phosphorus in the charged molten metal introduces a new factor, viz., the presence of the oxides of type $CaO_n\ P_2O_5$. Thus, suppose the charged metal loses 1.5 per cent. Si, 0.6 per cent. Mn and 1.8 per cent. P, then if the slags are finally inert they will have the estimated composition E of Table 8 (Fig. 8).

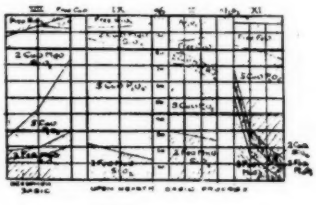

Fig. 8.

In actual practice the progress of a blow is shown in the analyses B, C, and D. The increase in the FeO and MnO content shows the effect of metal oxidation, which increases as the blow progresses. The silica content falls as the phosphorus and lime increase.

There have been added to the analyses an estimate of the possible liquid slag constitution. It will be noted that there is a gradual increase in the contents of the inert silicate $2FeO\ SiO_2$, and of the inert lime phosphate $5CaOP_2O_5$. The latter would appear to grow at the expense of the inert lime silicate $2CaO\ SiO_2$, and at the increasing temperature obtained as the blow finishes excess lime is taken up.

The final slags contain free lime, whereas the earlier slags contain free silica.

The example given is a capital illustration of the correctness of the statement already made that the working slags tend towards the inert condition. This is well brought out by plotting the results.

Open Hearth Slags.

A charge of pig-iron may be melted in an open-hearth furnace without any additions of ore, providing the furnace atmosphere is kept strongly oxidising in character.

Here the molten iron is oxidised and forms the basis of the refining slag. In such a case the theoretical slag resulting from the elimination of, say, 1.5 per cent. Si and 1.0 per cent. Mn, supposing the iron oxide to unite with the silica and manganous oxide to form a meta-silicate $(FeO\ MnO)\ SiO_2$ would have the composition:—

FeO + MnO = 56 per cent.; SiO_2 = 44 per cent. approx.

In normal practice the oxidising agent is added as iron ore (Fe_2O_3), and as the furnace temperature is higher than the fusion point of the stable silicate $(2FeO.\ MnO)_2\ SiO_2$, this ortho-silicate form is probably the basis of the liquid slag composition.

It is proved that such silicate is capable of dissolving excess silica, and in practice 30 to 45 per cent. SiO_2 is found dissolved in 55 to 65 per cent. of the 2RO silicate. $(2FeO.MnO)SiO_2$.

During the working of an acid open-hearth charge the SiO_2 content gradually increases whilst the FeO and MnO content (sum) decreases.

Table VIII.—*Composition of Basic Bessemer Slags.*

	FeO MnO	SiO_2	CaO MgO	P_2O_5	Inert 2FeO SiO_2 MnO	Free SiO_2	Inert 5CaO P_2O_5	2CaO SiO_2	Free CaO
A.	21.4	17.9	41.0	17.5	30.4	9.0	58.5	—	—
B.	12.1	39.2	45.0	2.6	17.2	12.8	7.8	61.1	—
C.	13.5	29.8	47.8	7.8	19.2	6.9	23.4	50.5	—
D.	20.5	14.9	48.5	14.9	29.1	—	44.7	18.1	7.8
E.	33.3	16.8	33.0	16.8	46.5	—	51.0	—	—

(To be continued.)

The Manufacture of American Steel Castings.

By W. H. Woodhall.*

A pattern must be made from the blue prints of the engineer, and from this pattern eventually will come the finished product, step by step. Due allowance, of course, must be made for shrinkage. It is in the pattern-shop that the simplification of the moulding must take place, for one cannot, as a rule, rely very much upon the core-maker or moulder to know the best steps in the manufacture of a casting, so that, as it proceeds through the shop, it will go along smoothly without hesitation at any one place. To hesitate at any point is loss, for in a tonnage foundry the profit depends mostly on production, and very little profit is usually had on orders in which only a few castings are desired. The chief pattern-maker then must be a man who will be able to foresee the entire procedure of the casting.

A question arises in the pattern-maker's mind. Will the finished casting be all right with normal shrink holes in it, or will it have to be made with expensive heads and risers to take care of the shrink and the gas? Repairing is a very important item in the pattern-shop, for in a steel foundry ramming and constant use of the pattern soon put it out of commission, and it must be examined very thoroughly. If the job will warrant the expense, aluminium patterns are cheaper in the long run.

Moulding Machines.

After the pattern is completed, together with core-boxes and core prints, it goes to the foundry and core rooms. Wherever a job can be made on a machine in order to get out a large number of moulds, it is by all means done, for production must be maintained. More than ever before is it necessary to use machine methods of moulding, for skilled moulders are scarce. It is impossible with present-day tendencies to get a young man to learn a trade by the old method, therefore there are fewer good moulders to-day than there were a few years ago, and it is necessary to adopt new methods. Probably the jolt machine is as good an illustration of machine methods as exists for maintaining production. With it one good moulder can direct several machines and make good castings as a result. Thus it is possible to increase production by means of unskilled labour.

Moulding Methods.

More and more, green sand work is supplanting dry sand moulding. As a rule the best castings can be produced from green sand drag-moulds and a cover core made of dry sand. Most of the dirty castings are produced by "washes" from the top of mould in green sand cope work.

Dry-sand moulds are generally made when the sections of resulting metal will be large, and when the casting must be machined. Dry-sand moulds should do away with swelled castings, and give a fairly uniform casting throughout. Clean shaving joints about 1 in. back following the mould contour and approximately 1-16 in. to ⅛ in. should be made. The thickness of this shaving depends, of course, upon weight of casting. Dry-sand moulding cuts down the loss from scabbed castings.

When thin sections of metal have to be cast, the green sand has a natural give that is beneficial when the molten metal pours into the mould. Fewer cracks and better castings are the result. Green-sand moulding is the cheaper method. It eliminates drying ovens, extra crane service, and a dry-floor man to put up moulds after drying. Thus green sand increases production. Moulds must be made in heavy steel-flasks for dry sand work, and this is a considerable expense, for all lifting must be accomplished by means of crane service. In green moulds, wooden flasks can be used. These can be turned over by hand, and thus will save expensive crane handling. It is said that wooden flasks are expensive, but the increase in production more than offsets the cost of the flasks. Wherever green sand can be used, it is the more economical in the end.

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Labour-Saving Devices.

Labour-saving devices play an important rôle to-day as never before, because production has been the great cry. Pneumatic rammers for both moulder and core-maker are absolutely necessary. Good crane service is essential. Sand mills and sand distribution are probably the best means of maintaining the output. A sand mill, designed to produce good mixtures and to distribute the finished sand, are essential. Very little hand-shovelling or tempering is therefore done, and the moulder has more time to do good work. An overhead sand-distributing conveyor device is ideal for the large foundry, as this allows the crane free headway to attend to other needs. In a large foundry, this one item alone cuts down a great deal of handling expense. While production is the cry, the foundryman must not forget that quality also must be maintained, for if many castings are scrapped from inferior moulding because of hurry and haste, then production lags behind also.

Acid or Basic Melting.

Probably the most important factor in the steel foundry is the metal itself. If the raw materials used in the acid open-hearth process are not of the right kind, difficulty is encountered at the inception. In acid open-hearth practice, no phosphorus and sulphur are removed from the steel, and there is even a slight gain in these impurities, while in the basic furnaces the conditions are such that slags are used in the basic furnace, and in order to facilitate the removal of phosphorus and sulphur the steel is often refined down to a very low content of carbon, which makes it more easily oxidised, and hence promotes the absorption of oxides. Add to this the fact that very impure grades of scrap are largely used in the basic furnace, and that the de-oxidising additions are generally so used that their effect is much less complete than in acid practice. Therefore, there is an array of considerations that point clearly to the superiority of acid over basic open-hearth steel. In some shops it has been found that this superiority can be measured roughly in terms of strength, and that for equal strength, basic steel must have five "points" more carbon than acid steel.

It is recognised throughout the States that the acid open-hearth is in most cases the best process for the manufacture of steel castings. This statement may be open to some challenge, but for both production and quality acid open-hearth steel is preferable in the tonnage foundry.

Most of the present-day American specifications for steel castings call for phosphorus not over 0.05 and sulphur not over 0.05 per cent. As these two elements are not removed in the acid furnace, our raw materials must then have not over 0.04 per cent. All raw materials coming into the yard must be analysed to determine whether the steel conforms to these requirements.

After many years of experience several noted authorities give the following as specifications for raw material to be used in acid open-hearth work:—Acid pig-iron: Si, 1.5 to 2.0; S, 0.03 to 0.035; P, 0.03 to 0.035; Mn, 1.0 to 2.0; and C, 3.5 to 4.0 per cent. Acid scrap: Si, 0.20 to 0.30; S, 0.035 to 0.04; P, 0.035 to 0.04; Mn, 0.65 to 0.75; and C, 0.15 to 0.25 per cent.

The specifications to which the metallurgist must work for finished castings depend upon the service to which the castings will be subjected. Most work in a tonnage foundry is of the railway class of castings. A summary of this type of specifications follows:—

1. *Scope.*—These specifications cover all steel castings for passenger and freight equipment cars, including couplers, truck bolsters, truck side frames, yokes and miscellaneous castings.

2. *Process.*—The steel may be made by open-hearth, crucible or electric process.

3. *Heat Treatment.*—Castings shall be allowed to become cold. They shall then be uniformly reheated to the proper temperature to refine the grain and allowed to cool uniformly and slowly.

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4. *Chemical Composition.*—The steel shall conform to the following requirements as to chemical composition:—C, 0.20 to 0.37; Mn, not over 0.75; P, not over 0.05; and S, not over 0.05 per cent.

5. *Ladle Analysis.*—An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulphur. The analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform with requirements specified in Section 4.

Physical Properties and Tests.

6. *Tension Test.*—The steel shall conform with the following requirements as to tensile properties:—Tensile strength, 65,000 lbs. per sq. in.; elastic limit, 0.4 to 0.5 of tensile strength; elongation in 2-in., not under 22 per cent.; and reduction in area, 35 per cent.

7. *Test Specimens and Annealing Lugs.*—Specimens for use in testing machine must be made according to sketch submitted. Annealing lugs must be attached to castings so that they can be easily broken off by inspector. It is very easy to see, then, that the work to be done by the finished casting depends on careful control of chemical analysis.

Dirty *versus* Clean Steel.

In order to meet specifications at all times the metal must be uniformly clean. By that is meant the metal must not show segregation due to impurities. It is a well-known fact that impurities such as sulphides and slag inclusions cause segregation. Immediately surrounding these inclusions is found a streak of almost pure iron. The iron carbide, in whatever form it may be present, will then collect itself further from the inclusions, thus making a segregated area of one streak of pure iron and then a streak of the harder portion of steel, namely, iron carbide and iron together called pearlite. These segregated portions of the steel often go under the name of ghost lines. If there are excessive ghost lines, there is weak metal, and it will not stand the strains that a more uniform steel will allow. The least number of these ghost lines, then, is most desirable for a good clean steel. Alumina often gets into the metal from the ladle linings that are made with fireclay. This is also a detriment to good steel, and makes for weakness.

There is only one good way to distinguish dirty steel from clean steel, and that is by aid of the microscope. More dirty steel results after it passes from the furnace than in the furnace itself, for in the furnace the high temperature keeps the slag mostly on top. The place to look, then, for most of the troubles when dirty steel is being poured is from the ladles or from washes from the upper cores or copes in our moulds.

Dirty steel is not only a bad product, but causes trouble throughout the entire shop. It is very hard to anneal properly, and many times does not get the good refinement of grain that is so essential to good castings. In the author's experience more dirt gets into the steel from the ladle linings than from any other source. If the ladle refractory has been carelessly applied, there is great danger of large pieces coming off and being entrapped in the metal. It may be said: "Why, it will rise and become part of the slag," but once a heat is tapped and the pouring into the moulds is commenced, suction plays a part, and a great deal of the ladle lining finds its way into the steel. The author has proved this in several cases by metallography. In some extreme cases many castings were scrapped on account of excessive cracks, due to slag lines, the slag being the ladle refractory which had been absorbed by the metal.

The Open-hearth Furnace.

The raw materials used, about 20 per cent. pig-iron, 80 per cent. scrap, are now taken from the yard, loaded in tubs on cars and taken to the furnace floor. Here the charging machine picks up each tub, and deposits it in the furnace. A charging machine is certainly a necessity in a tonnage foundry, for the more quickly the charge is made the faster the melter can get out the finished metal. A heat is made in approximately five hours. Tapping, repairing of furnace lining and refilling take up an hour's time, so that the melter is able to get out four heats a day. The best of furnace-sand is not too good for the bottom and banks of the furnace as poor sand results in an extra heavy slag and bad cutting of bottom. A chemical analysis of furnace bottom sand is almost useless, as it is physical properties that are essential. The sand must have high silica content, and must contain just enough bond to fuse properly and "set" in place. High temperature should not cause it to run, for this, together with slag action, causes the lining to "cut." In a foundry producing only a few grades of steel such as soft and medium steel, carbon of 0.20 to 0.40 per cent., the calculation of the charge is very simple. When the charge is melted the melt is ored. The manganese and silicon are first oxidised and make up the slag. Then the carbon commences to "boil" out. The consumption of ore should not exceed 6 per cent. of the weight of the charge, and in most heats will be below this figure. Pig-iron, high in silicon and low in manganese, may frequently cause embarrassment in that the heat melts high in silicon, with the result that much time is spent in elimination of the silicon by means of ore. Confronted with such conditions the melter must cut down the proportion of pig-iron so that the charge will be low in carbon, yet contain enough silicon, when melted, to protect the carbon from oxidation. The bath will then melt at about the carbon content of the charge, and we can run it down with little or no ore, or if it melts too low in carbon and is hard to heat because it will not "boil," the furnaceman can "pig" it to assist operations.

Sampling.

A test of the metal is now taken by means of a small test spoon, which is first warmed and then coated with slag, then dipped deep into the bath and rapidly withdrawn. A small test-mould is filled, and any metal remaining is poured slowly from the spoon to judge its temperature. If it pours out clean from the spoon it is very hot, the more remaining in the spoon the colder and wilder the metal. The slag adhering to the spoon is also examined, and by its colour the progress of the elimination of iron oxide is watched. When the steel is cold and wild it scintillates and "rises" strongly in the test mould. By the fracture of the test-piece, or by colour-carbon analysis, the melter estimates the carbon of the bath, and judges whether or not more ore is needed to eliminate the carbon still further.

The best metal is made by adding small amounts of ore rapidly at first and then more slowly. Of course, if the carbon is not "sliding" down fast enough in the melter's opinion, more ore must be added to cause it to do this. The effect of the ore should be almost finished at least thirty minutes to an hour before tapping, and an ideal practice is that of getting all the ore into the furnace as soon as possible less rapidly, and then very slowly. By this practice the iron oxide in the slag, available for oxidising silicon, manganese, and carbon, is practically all exhausted before the heat is tapped, and the iron oxide is largely eliminated from the steel and taken up by the slag. As the effect of the ore wears off, the "rise" becomes less in the test-mould, the slag grows less black and watery, and the metal pours more cleanly from the test spoon. When the carbon is low enough that the heat may be tapped, the metal should be so hot that it will all pour out clean from the test spoon. If it does not the temperature should be increased, holding the carbon up by additions of "pig" or ferro-silicon until the steel will pour reasonably clean. If the ferro-silicon, pig, or ferro-manganese used as re-carbonisers are added in the furnace, which is the proper place, a last test after they are all melted does not come amiss.

This last test, if the silicon (or both silicon and manganese) has been added, should pour perfectly clean from the spoon and the test should be quiet and flat in the mould.

Some furnacemen add ore till the carbon is racing down and the steel full of oxides, the tests skulling the spoon and scintillating and rising in the mould, throw in ferro-silicon and pig-iron to check the elimination of carbon, tap the heat as

soon as these are melted, add the ferro-manganese in the ladle and pour the steel. They melt the metal hot and keep it hot, but the metal is full of oxides, wild in the moulds, and of very poor quality. By heavy additions of manganese and silicon and frequently of aluminium, the steel is killed sufficiently to make fairly sound castings, but it is not good steel.

Cleaning and Inspection.

After the moulds have cooled, so they can be handled easily, they are taken to the knockout floor, where the castings are shaken out. This floor consists of a great number of grid openings through which the sand goes to large underground hoppers, and these in turn feed several belt conveyors. The sand is then conveyed out of the shop to waiting trucks, which dispose of the burnt cores and sand. Some of the sand is used over again in the new sand mixtures, and is taken to the sand mills. The underground conveyor system is a very great time saver, and increases production. After the castings are shaken out, some of the risers are knocked off, if there is a section sufficiently thin that this may be done. At this point there must be the first inspection of the castings, and a good inspector is essential. He must be a rapid worker for the progress of the castings should never be halted, as this results in loss, but he must discover as many as possible of the castings that must be scrapped. The inspection is quite necessary at this point in order to prevent the heavy cost of putting the castings through the sand blast and cleaning room, finally to discover that castings must be scrapped due to mispour, cracks, shifts, swells, etc.

From the knock-out floor the castings are conveyed to the sand blast, where all adhering sand is cleaned off in the quickest and most efficient manner known to-day.

The cleaned castings are next conveyed to the cleaning room proper, where the second inspection takes place, and where hitherto undiscovered poor castings are found and scrapped. The fins, risers, gates and heads are next burned off by oxy-acetylene burning torches. The proper manipulation of these torches is quite an art, and requires the best of skilled labour.

The next step in the finishing of the casting is to grind down rough surfaces or protruding portions, so that the castings will be square or will fit the finished gauges. The larger castings are taken to blocks above which hangs a swinging grinder. Attached to these grinders are two long handles which enable the operator to turn the grinding wheels in any direction, and to exert pressure on the surface to be ground. Small castings are ground on ordinary stationary grinders. The best wheels to use are either corundum or carborundum, as these quickly cut off the undesirable portions of the steel. Portions that cannot be reached by grinders are chipped by power chippers. Holes are reamed out by power hammers. The casting now presents a fair appearance, and is ready for the refining of its coarse crystalline structure.

Annealing Furnaces.

To ensure the greatest production, these furnaces must be so designed as to be continuous, that is, one batch of castings being heated while the other batch is cooling. It is probably better to let the engineering department design the furnaces, using approved methods of getting the proper combustion chambers for the type of fuel at hand. If using oil, burners that use the minimum amount of fuel and use vaporisation by air are desirable. A great many burners to-day take more fuel oil than is actually burned. Either the mixing with air or steam is not carried out properly or the burner is poorly designed. It is a good thing to test out several types of burners by means of oil meters and see which gives the most heat for amount of fuel used. Fuel oil used indiscriminately increases cost of production, for in a large steel casting foundry many furnaces are necessary. Another very important thing is to get proper temperatures in the annealing furnace for the kind of steel being annealed.

The coarse structure of steel castings is not refined at temperatures slightly above the upper critical range. A much higher temperature is necessary to break down this coarse grain. The author's experience has been that the higher the temperature at which the heat has been poured into the mould, the higher the annealing temperature must be. A simple way to test this is to pour from the test spoon into test ingot a sample from the furnace and note the number of seconds required before freezing of the metal. Similar ingots were made, one from an ingot in sixty seconds but which had to be heated to about 980 deg. C. to refine the structure, while the other was cast and took only forty seconds to freeze and annealed properly at 925 deg. C. When very thin sections of metal are found, higher temperatures have to be used than for thicker sections. These castings take a much higher annealing temperature. It is the duty of the metallurgist to determine the proper temperature at which good refinement of grain is accomplished. To-day more than ever before it is quite necessary to use a good pyrometric system to measure temperatures within the furnaces. The thermocouples are generally placed in the furnace roof. This necessitates getting the difference in temperature between the roof of the furnace and the castings themselves.

Annealing Period.

Castings of 1 in. section at the thickest section should be held for one hour. After the proper soaking the casting can be cooled by either drawing from the furnace or allowing to cool in the furnace. Cooling in the furnace is true annealing, but results in a larger grain structure than that caused by cooling in the air. Most of the present day work is cooled in quiet air, and this makes for small grain size.

As the foundry must always keep up production without the sacrifice of quality, it is quite necessary to have one truck of castings ready for the oven as soon as the heated castings are ready to draw. This completes a cycle of operations, and the castings are then ready for the finishing touches. If the castings have been heat-treated properly they will not show excessive scale, unless the ovens are leaking large amounts of air. If the flames are kept slightly reducing or even neutral it gives the best looking castings. An oxidising atmosphere in the ovens always gives thick scaled results which are undesirable.

The annealing operation then consists of:—(1) Heating the steel uniformly to the proper temperature; (2) soaking it at this temperature to assure complete penetration, and (3) cooling until the colour disappears. This annealing process is of the highest value and importance, and scientific annealing implies expert supervision.

Some of the castings after coming from the annealing furnaces must be straightened. This is done while hot, so as not to put any permanent strains on the metal.

The castings, after being cooled, are then gauged, and any castings needing further work are finished completely. Some may have small shrink holes that are welded by an electric arc welder. This prevents their being scrapped entirely. Others may have to have a hole reamed a little larger. The final inspection is now made and the castings are sent to the waiting railway cars to be sent to their destination. All transportation other than crane service is done by means of electric storage battery trucks. These trucks keep things "moving lively" for material in constant motion spells success in the steel foundry.

Birmingham Exhibition.

The Technical Advisory Committee of the International Foundry Trades Exhibition has decided to hold a three days' Foundry Technical Congress. The days chosen were Wednesday, Thursday and Friday, June 25, 26 and 27. Technical sessions will be held each day under the chairmanship of prominent foundrymen, and a selection of papers will be submitted. Many prominent foundrymen have already promised to contribute papers. The sessions will be held in the afternoon from 3 to 5. Advance copies of the papers will be available.

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Sand Mill Developments.

The Universal System of Machine Moulding and Machinery Company, Limited, of 97, Queen Victoria Street, London, E.C.4, have recently placed upon the British and Colonial market two types of sand mills designed and built by their principals, Messrs. Bonvillain et Ronceray, of Choisy-le-Roi, near Paris.

Continuous Mill.

The larger, which is of 7 ft. 10 in. diameter, is for foundries which employ from day to day large quantities of sand.

It will be seen from Fig. 1 that the pan usually associated with sand mills does not exist. It is, however, replaced by a large circular plate worked by a rotation movement. On this plate are placed at intervals three sets of cutting teeth, made up of circular plates and concentric plates. These plates are easily replaced when necessary. The large plate is moved by a fixed pivot. This movement is arranged by a cog working on a toothed wheel fixed on the underneath side. It is supported during its rotation by three rotating wheels mounted on the supports of the foundation and by ball bearings placed on the base of the pivot column. The driving is made by fixed and loose pulleys.

To work this mill efficiently, it is advised by the makers that the sand is discharged by a chute into the centre of the mill. It is then automatically brought under the rollers, and as it passes from the rollers it is cut up by the teeth or plates shown in the illustration, after having passed under the rollers.

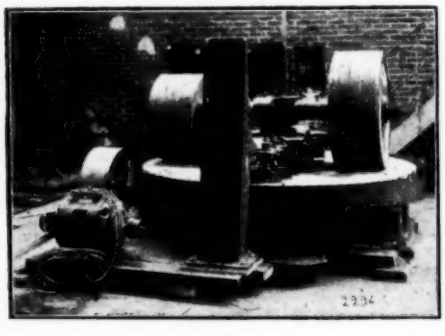

Fig. 1.—A New Type of Continuous Sand Mill.

It will be also noticed that one of the mullers is nearer the centre than the other one, consequently the sand is automatically worked, and eventually is discharged on the side of the plate. It should be also noticed the lightness of weight of the mullers or rollers.

It is the object of this mill to eliminate the weight of the rollers as much as possible in the sand mill so as to get a rubbing action on the sand and not a crushing action. It should also be noticed that to get this rubbing action it is necessary to rotate the table of the machine and the rollers at different speeds, and by this method this is attained. The principal characteristics:—Diameter of plate or table, 7 ft. 10 in.; diameter and width of milling rolls, 39¼ in. by 15¾ in.; diameter and width of fixed and loose pulleys, 27½ in. by 5½ in.: weight of one of the rollers, 1,100 lbs.; approximate weight of the complete apparatus, 7 tons; number of turns per minute of the pulley, 135 turns; power absorbed, 10 h.p. approximately.

Mill with Automatic Discharge.

The apparatus is shown in Fig. 2, and has been designed for use in ordinary foundries that have not a large demand for huge quantities of sand. The principle of this mill is similar to the larger one, and it has been thought necessary to revolve both the pan and the milling wheels at different speeds.

It is evident, however, that in the old type of sand mills having both the pan and rollers revolving it was impossible to discharge the sand except by shovel, which was long and laborious. In this particular mill it is possible to discharge sand automatically, or, in other words, the mill discharges the sand at one given point, so that it is possible to arrange to pass the sand directly into the disintegrator. This disintegrator is placed exactly under the point of discharge of the sand, so that it is not necessary to shovel the sand from one machine to the other.

In order to effect this, it will be noticed that the sides of the pan have been completely eliminated, and in their place two guides have been incorporated to keep the sand on the table. It will also be seen that at both sides of the pan and at each end of the milling wheels have been placed a series of teeth, which can be easily altered so as to change the direction of the sand, or can be replaced very easily after wear.

The sand is placed on the table of the sand mill, it then passes under one of the rollers, then through the series of teeth, then under the other roller, then through other series of teeth, and so on. When sufficient milling has been given to the sand the operator simply pushes round the handle shown in the illustration (Fig. 2) and the sand is discharged by the action of the revolving of the pan.

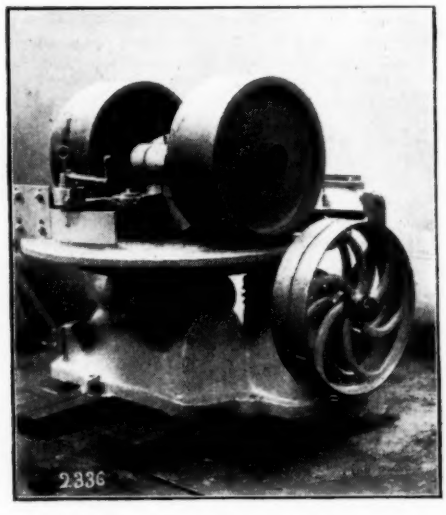

Fig. 2.—A Novel Paniess Sand Mill.

A further item which should be noticed with relation to this mill is the manner in which the centres of the milling wheels have been cut out, so as to keep down the weight, in order to get a rubbing action, and not a crushing action, on the sand. Both the pan and wheels revolve, and the wheels do not quite touch the table. In consequence, very little silt is produced during the milling of the sand.

Representatives of 250 steel-making firms met in Sheffield last week, and came to the conclusion that if the Government's proposal to abolish the McKenna duties is carried out a serious diminution in work in Sheffield and district will take place, involving a still further addition to the already grave unemployment problem of the city. Various estimates were given showing that a drop in steel orders would range from 33 1-3 per cent. to 50 per cent., owing to the effect of the abolition of the duties on the motor-car and allied industries. A deputation of manufacturers has waited upon Sheffield Members of Parliament at the House of Commons on the subject.

A provisional agreement has been signed between Vivian & Sons, Limited, and Williams, Foster & Company and Pascoe, Grenfell & Sons, Limited, in accordance with which a new company will shortly be formed to carry on the amalgamated businesses. Williams, Foster & Company and Pascoe Grenfell & Sons, Limited, are a public company with an issued capital of £100,000 in preference and £250,000 in ordinary shares. The Central Mining and Investment Corporation is largely interested in this company. Vivian & Sons, Limited, are a private company, the shares of which are held by family interests. Messrs. Williams, Foster are also owners of the well-known business of Grice, Grice & Sons, Limited, Nile Street, Birmingham, brass and copper tube manufacturers.

Nitrogen in Iron.

By J. Kent Smith, O.B.E.

For many years the impression has prevailed amongst a limited circle of metallurgists that one of the deadliest enemies to iron and steel with respect to physical attributes is to be found in nitrogen. And at the outset the writer identifies himself with this group in the most emphatic manner. It is only fair to state that several deservedly high authorities have declared to the contrary, quite possibly with correctness as far as the particular circumstances of their observations were concerned. The writer goes even further than many in so much as he has very pronounced views on the modifications of the hot working properties of steels brought about by varying nitrogen contents. The vast majority of industrial metallurgists completely ignore the whole question, thereby failing in recognition of one of the most crucial points involved in the practical results of the iron and steel industry.

Nitrogen Content is Difficult to Determine.

Admittedly the recorded results of nitrogen estimation in steel and iron are in themselves of the most conflicting character. Whilst the principles involved in its determination methods are comparatively simple the practice of those principles, accompanied as it is by varying and relatively large "blanks," becomes very difficult in the conditions of the works laboratory. But even were determination methods to be "straightened out," in the writer's view that might not necessarily affect the conclusions of the two schools of thought existing amongst those comparatively few who have given consideration to the subject. The simple determinations of the amounts of carbon and of hydrogen in sugar, in oxalic acid, and in petrol would not lead us very far in determining the properties of those bodies, nor would most meticulous further determination of the oxygen (present largely in the first two and practically absent from the last) throw light on the subject. Surely it is not a question merely of "how much" nitrogen there is in a steel, *but rather of how that quantum of nitrogen is combined.*

Elementary nitrogen which is simply occluded will obviously produce just as much harm as, and no more harm than, will other simply-occluded gas. But it is beyond doubt that nitrogen combined as nitride of iron (or even as cyano-nitride) in solid solution in ferrite, whether that ferrite be structurally free or a constituent of pearlite, may if present in sufficient quantity produce disastrous results both in hot fabrication and in subsequent mechanical attributes. Again nitrogen, "taken care of" by an element having a strong affinity for it, may be relatively almost harmless, as, for instance, in the case of zirconium nitride; it is certain that such an inclusion of nitride does no more harm than do other non-metallic inclusions of similar magnitude, such as the manganese-sulphide nodules present in all normal steels.

If metallurgists desire that iron and steel products be low in nitrogen-content there are two broad ways of handling the subject: either they must remove the nitrogen which has been allowed to enter into combination with the iron in present practice of iron-smelting processes, or they must prevent nitrogenisation in them. With respect to the former, they must face laws of chemical and thermal equilibria in the case of an unbalanced reaction.

Possible Elements for the Elimination of Nitrogen.

Dealing first with iron that *has been nitrogenised in the blast furnace*: the elements which have an affinity for nitrogen so strong as to be able to drag it away from its combination with iron are relatively few in number, and in their commercial forms are fairly costly. Nevertheless, many industrial conditions arise where one or more of these elements can be employed advantageously. But it must be remembered that commercial conditions, aside from all other questions, preclude complete denitrogenisation being brought about. One of the elements, and possibly the best known, is vanadium, another titanium, and yet another zirconium. On account of the dissociation points of some of their carbides being very high, their carbonless alloys *must* be used in every case for the successful treatment of *cast iron*, since such dissociation points most undoubtedly are several hundreds of degrees above the commercial "handling" temperature of it. Whilst the element Boron has a strong affinity for nitrogen, it is a very dangerous "medicine" to be given to iron and steel, owing to the proneness to formation of the dreaded and disastrous "third constituent," hence the employment of the element is not dealt with in these notes.

Vanadium in Cast Iron.

The vanadization of foundry iron is frequently resorted to in good practice for the preparation of special articles; as the result not only is ferrite indirectly toughened and densified through removal of its dissolved nitride and suboxide deleteria, but it is directly toughened by solid solution in it of a small and practically constant amount of vanadium. Any balance of vanadium goes to strengthen the carbides. Vanadium is further attended by the great advantage of its scavenged products, having a remarkably fluid, and consequently easily separating, form. The continued experience and practice of some of the large producers of complicated internal cylinder castings and of very high-pressure hydraulic valve-bodies find two of the industrial applications of these facts.

If titanium be the agent employed for denitrogenising cast iron, the "carbonless" alloy of it must be used, since the temperature dissociation-points of the carbides of titanium are so far above the "handling" temperature of cast iron that in ironfoundry work the ordinary carburetted ferro-titanium fails to function, partly on this score and partly by reason of its necessarily attendant insolubility. When applying titanium to cast iron it must not be forgotten that the excess over that taken up in denitrogenising and in deoxidising passes into solid solution in the ferrite, that the ferrite thereby is not further "directly" toughened as in the case of vanadium, and that chilling properties of the iron are also reduced; in the process of vanadization they are increased. But in the preparation of cast-iron articles where super-cleansing is desired without interference with "chill" properties a composite alloy of vanadium, titanium, and iron may be desirable.

Little is recorded concerning the treatment of cast iron with zirconium; without doubt such results as have been achieved point to much potential value following upon the correct use of carbonless ferro-silico-zirconium, preferably containing a percentage of aluminium.

Nitrogen in Steel.

The beneficial results attending the denitrogenisation of steel are much more readily observable. In those otherwise normal steels of which vanadium forms a component, time and again has direct analysis shown a low content of nitrogen. The writer here would cite a practical fact which in his opinion bears strongly upon the subject in hand. Some years ago he had occasion to produce in considerable quantity a special steel—the product of the crucible—and the best service results from that steel were invariably obtained as the result of using one of three certain Swedish irons as the crucible base. Simultaneously he had under his supervision open-hearth plant wherein a high grade of dead mild steel (produced from British pig and plate scrap on the well-known A.B. system) was manufactured. This steel, of great purity as far as ordinary analysis showed, when used as a crucible base, did not give results at all comparable in service value with those obtainable from the Swedish irons. An open-

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hearth charge was made in the normal A.B. manner, running as dead soft as possible without undue oxygenation. No additional manganese was added, but the steel was treated in the ladle with an addition of 0.15 per cent. of vanadium. In spite of the fact that the manganese content of the steel was under 0.045 per cent. the steel rolled well, though naturally a shade roaky, and the service value of the crucible steels in the manufacture of which this vanadised British steel was used as a base, and many tons of which were made, was in every way comparable with that resulting from the employment of the selected Swedish irons.

Titanium Steel.

The correct addition of titanium to steel undoubtedly brings about great improvement by super-cleansing. It must not be forgotten, however, that titanium is a very powerful deoxidiser, its avidity for oxygen being greater than that of vanadium. Wherefore, in order to obtain the best work from it, metallurgists should never exhibit it to the steel to be treated until that steel has been deoxidised to the fullest extent by ordinary means. While the carbonless alloy of iron and titanium—containing some aluminium—is preferred by some workers it is quite admissible to use ferro-carbon-titanium produced by electric smelting, provided that the steel to be titanised thereby be really hot; if it be not, trouble may be experienced on account of lack of carbide dissociation and concurrent insolubility. The high heat of the finished metal bath also renders it possible to "hold the ladle" for a considerable time before casting, which again is all to the good, since it favours the more complete separation of the titanium-scavenged products—not so fusible, and consequently not so readily separable as those of vanadium.

The results, published in copious detail, of the lengthy and complete inquiry into canning service of plain and titanised steels recently carried through jointly by the National Canners' Association, the American Can Company, and the Titanium Alloy Manufacturing Company of New York, are worthy of careful, detailed study. Much of the steel improvement, following titanium treatment, is undoubtedly due to the lowering of nitrogen content. In this country some remarkable results have just come to the writer's hands in connection with the subject of greatly increased resistance to wear of tram rails made from titanium-treated steel. No doubt exists in the author's mind that the subject of atmospheric corrosion is one which is inextricably wrapped up with that of open-air rail-wear: in reducing the liability to corrosion of steel, partial denitrogenisation and more complete deoxygenation undoubtedly play very important parts.

Zirconium and Nitrogen.

Quite a number of more or less desultory results have been published from time to time by different workers on the effects of zirconium additions to steel. The most complete, and certainly the most interesting, of these are to be found in the publications of F. B. Becket, of the Electro-Metallurgical Company of America. It is certain that the alloy industry and the special steel industry do not recognise fully the deep debt of gratitude which they owe to this indefatigable and careful worker, though it is pleasing to note partial recognition of it in the recent presentation to Mr. Becket of the Perkin Medal of the U.S.A. A recent publication of his describing some of the specific effects determined in the zirconizing of some 350 experimental heats of steel is of profound interest. Excellent mechanical results were obtained by the heat treatment of zirconised, but otherwise plain carbon steels. In summarising, Becket records that "minute yellow cubic crystals of zirconium nitride are generally observed in steels treated with zirconium in excess approximately of 0.10 per cent. They are limited in number, and represent that residual of the nitrogen content of the steel which was fixed by zirconium but not slagged off prior to solidification. These crystals, as such, do not exert a harmful influence on the steel."

Becket further notes that zirconium has the property of chemically combining with sulphur to form an acid-insoluble compound, and that *under a given set of operating conditions* a linear relation exists between the percentage of sulphur fixed and the amount by which the added zirconium exceeds 0.15 per cent. But most germane to the subject of this article are Becket's fully-recorded observations on the extraordinary beneficial effect of zirconium treatment upon the hot rolling properties of steel. He cites an instance of steel ingots containing 0.185 per cent. of sulphur with only 0.15 per cent. of manganese having been rolled to plate and sheet free from hot cracks and seams when the steel had been treated with 0.22 per cent. of zirconium, whereas unzirconised steel containing precisely the same proportion of sulphur and manganese had broken to pieces in every case on its first pass through the rolls. Broadly speaking, he is inclined to attribute the chief benefactions of zirconium to fixation of the sulphur (and, of course, decomposition of the iron sulphide). Whilst not doubting this to be a true deduction of a contributory cause, the writer considers as much more important the fact that he shows by record the zirconium addition to have eliminated two-thirds of the combined nitrogen which was present in the original steel before zirconium treatment. Certainly his rolling-mill experiences matches in a startling manner with some experiences of the writer later to be detailed, where freedom from dissolved nitride was obtained by completely different means.

The Entry of Nitrogen.

Obviously, elementary nitrogen cannot be the means of the entry of nitrogen into iron; if it were, any iron or steel made by present-day commercial processes must contain quantities of it. Without doubt the combination of nitrogen and iron is effected in the blast furnace, and there by means of a "cyanogen" reaction. In the light of our present knowledge no precise pronouncement as to the nature and mechanism of this reaction is possible. But repeatedly has it been recorded by careful observers that blast furnaces, when producing (in their hot zones) undue quantities of potassium cyanide, produce pig-iron which converts to steel of poor hot-working and mechanical qualities.

Premising that in ordinary practice some nitrogen is introduced into combination with iron in the blast furnace, the question rises as to whether this nitrogenisation can be prevented, if not entirely, at least mainly. The readiest answer is that in blast-furnace practice incidental to the production of the best Swedish pigs, the "cyanogen compound," somewhat minimised in amount, is automatically dealt with at the moment of formation. Fuel burden and conditions and temperature of the blast are the items responsible for the lessened formation of the cyanogen compound. The chemical removal of the major part of such as *is* formed is automatically brought about; high-grade Swedish ores contain oxide of vanadium in considerable quantity, and since the fully (or partially) reduced product of that oxide has a greater affinity for the nitrogen compound than has the iron, and moreover produces a nitride insoluble in iron, such nitrogen is slagged away as is not "fixed."

A Possible Explanation of Inherent Properties.

At this point it might perhaps be legitimate to speculate as to how far questions of nitrogen content relate themselves to the marked differences between cold-blast pig-iron and hot-blast pig-iron made from the same raw materials by ordinary British practice. "Total" carbon protagonists may consider that the point settles itself, but is it not possible that total carbon here is indicative rather than determinative? The very factors which would determine low-carbon saturation would be indicative of lowered temperature-intensity at the "hottest spot," and this would make for the production of less cyanogen compound. Indubitably the form and distribution of the graphite in cold-blast irons constitute factors of their superiority: that they form the only factors is questionable.

Thus far the elimination, or the (insoluble) fixation of nitrogen only has been dealt with: the result of any method of procedure along these lines must fall short of completion in so far as factors of mass temperature and time determine.

The logical course to pursue, where it is possible, is to avoid the *cause* of nitrogenisation, or, in other words, entirely to preclude "cyanogen reaction." To do this the avoidance of intense temperature at any particular spot or zone in the initial reduction of metallic iron from its mineral source is indicated as paramount.

Low-Temperature Reduction of Ore.

The writer has always contended that, apart from considerations of financial economy, the most important attribute of iron produced by low-temperature (or solid) reduction would be found in its freedom from nitrides. The high degree of excellence of those irons, which may be described as historic or classic, is, without doubt, at any rate partially to be explained in this regard. It must be remembered that for many centuries the world was entirely dependent for its supplies of metallic iron upon processes of "solid" reduction. With continued technological developments of the rotary kiln and of powdered fuel application, the question of bringing the production of solid-reduced iron to a bulk stage, commensurate with modern requirements as to mass, could only be one of time. And it may practically be said that the time has now arrived. A little time ago the writer was entrusted with the conversion into steel of several tons of granular iron produced, from very ordinary British iron ores, by a modern process of low-temperature reduction. Plain carbon steels of varying types were made from it, all of which on test showed combinations of static and dynamic excellence ordinarily high for carbon-steels of very ordinary analysis. Particularly to be noted was their susceptibility to improvement following heat treatment: generally speaking, the ease with which a sorbitic structure could be obtained, and the persistency with which it was retained, were specially noteworthy. Following upon general observations made during the fabrication of those steels, the writer was impelled to make some drastic empirical trials.

Practical Tests.

One of the steels (mild) was deliberately sulphurised up to 0.16 per cent., only 0.28 per cent. of manganese was present to "take care" of this, yet the ingots, which by all canons when worked hot should have cracked, pulled, and disintegrated very badly, forged perfectly under normal conditions. This observation, when considered side by side with the observations of Becket on the mill behaviour of zirconised sulphur-bearing steels, whose nitrogen content had been reduced and harmlessly "fixed" as to its balance, gives much food for thought. Especially does it so when we take into parallel consideration the recorded observations of Braune and others that steels, perfectly normal as to their contents of ordinary impurities, when unduly high in nitride content had proved badly red-short and yellow-short in the forge.

Scrap, from another mild-heat, was used as a crucible base, was carburised to 0.75 per cent., and was deliberately phosphorised to 0.25 per cent. A piece of it was forged to ⅝-in. rod, a short length of the rod cut off, heated red hot, and jumped to a disc 1⅝-in. dia. without any edge work. Nevertheless this disc, whose forging was finished almost blue, showed no edge cracks. Another bar of it was forged to a chisel which was blast hardened and tested under severe comparative conditions. Excellent crucible-steel chisels, under these conditions, had their work cut out to withstand 500 blows before destruction. Yet the chisel of the phosphorised non-nitrogen steel, after 540 blows, showed no signs of having been used.

Still another portion of the sulphurised steel scrap was crucibly melted, carburised to 1 per cent., and deliberately phosphorised to 0.27 per cent.: its ingot forged perfectly, and the resultant bar made excellent edge tools.

Body.

The writer was brought up in a metallurgical school which was accustomed to regard with derision, or at best with complacent tolerance, the old-fashioned workman's pronouncements concerning "body." Doubtless if "body" be regarded in the light of a positive entity such derision may have been fully justified; if, however, the term be translated into one of negative entities it behoves one carefully to think. How far the old-fashioned idea of "body" is involved with considerations of combined nitrogen is a point worthy of much deliberation.

From a welter of observations the fact clearly emerges that the shibboleths regarding permissible percentages of sulphur and of phosphorus may, and should, be modified quite considerably in varying sets of conditions. Certainly Shakespeare's dictum, hackneyed though it be through oft-quotation, that "there are more things in heaven and earth . . . than are dreamt of in our philosophy," nowhere finds a wider field of application than in the problems of steel metallurgy.

Foundry Queries.

Core-Drying Stoves. (Page 332, April 24).

In reply to "Iron Founder," the essential requirement of a core-drying stove is absolute uniformity of temperature, so that the rate of drying and the temperature at which this is accomplished can be maintained with equal uniformity.

A state of atmosphere should be created capable of absorbing and retaining the maximum amount of moisture. Throughout the oven and at all times the oven atmosphere should be under control. Good core-drying can only be carried out by good oven control.

In modern ovens flues are provided to carry off the steam from the cores, and if any system of ventilation is adopted, it should be such that the current of air rises to the top of the oven to carry the steam off with it. Such ventilation as suggested is not recommended.

The oven temperature depends largely on the binding agent used, from 170 to 200 deg. C.

A temperature of about 120 deg. C. should first be maintained to drive out the water, and then the temperature raised to decompose or vaporise the binding agent.—DISCE-DOSCE.

Coke Consumption and Lining Thickness. (Page 344. April 24).

"T. M. G." should use a 4½-in. brick lining for his 30-in. outside diameter cupola, the bricks being dipped in thin clay water. The less clay that adheres to the brick the better. The lining should be kept about ¾ in. away from the shell, and the space filled in loosely with moulding sand and very fine brick. The interior should be well daubed for a thickness of ¾ in., the daubing being washed with a strong brine and fine clay, which will give it a good glaze and reduce the amount of chipping required so much in small cupolas.

The above lining will give an internal diameter of about 18 in. These small cupolas are not very successful unless special care is taken to keep them clean. This is assisted by giving a taper to the cylinder, and further prevents any wedging up of the metal.

The number of tuyeres should be three, having an area of 23 sq. in., the air pressure in ounces per sq. in. being about 7½ and the velocity 27 ft. per second.

Great care should be taken in cupolas of this size in the weight of the charges; if layers of metal and coke are too thin, there will be two charges of metal in the melting zone at one time. If very hot iron is desired, the coke layers should be made thicker, with a consequent diminution of the rate of melting. It is not good practice to strive for high fuel ratio in a small cupola at the risk of a dull heat; the loss on castings will outweigh any saving on coke.

For the coke bed there should be sufficient coke to locate the top of the melting zone about 20 in. above the tuyeres, and the amount of coke between each charge of the iron and the preceding one should be not less than 10 per cent. of the iron. The economic rate of coke burning per sq. in. of cupola area at tuyere level per hour is about 1 lb. For a cupola 18 in. inside diameter this would be about 255 lbs., using a good quality coke of, say, not less than 88 per cent. carbon.

For small cupolas it is most essential that the coke is of good quality, with a freedom of "black ends"; all "fines" should be sieved out, and the coke perfectly clean.—DISCE-DOSCE.

The Manufacture of Pearlitic Cast Iron for High-Temperature Engines.*

By Arthur Marks, F.I.C.

The manufacture of castings for parts subjected to high temperature, such as internal combustion engine cylinder covers and pistons, has called for a cheap material to withstand exceptional conditions. This Paper gives the writer's attempts to produce pearlitic cast iron in the cupola with a view to obtaining the strongest material possible for this class of casting.

An examination of the cracks which occur in pistons and which are shown in cylinder covers shows that there are two main causes of failure. (1) Star crack radiating from a local centre (Fig. 1); and (2) cracks which extend right across the piston or between holes in the covers (Figs. 2 and 3).

Cracks of the first type are the most interesting from a metallurgical point of view. These are associated with oxidation of the graphite in the material and items in the composition, such as sulphur and phosphorus.

The second type of crack is usually associated with casting conditions, and can usually be overcome by modification of the method of casting the job. They are, in fact, structural strain-cracks due to chilling the material in order to obtain a dense and close metal where the piston or cover is fairly thick and consequently likely to

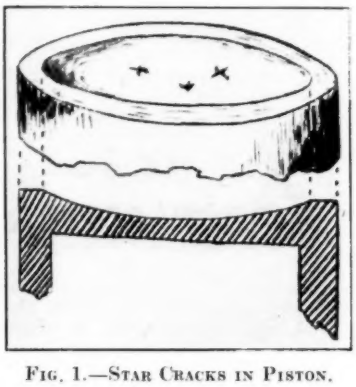

FIG. 1.—STAR CRACKS IN PISTON.

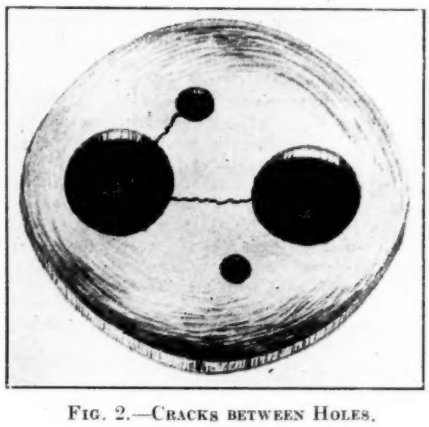

FIG. 2.—CRACKS BETWEEN HOLES.

be subject to porosity. Generally speaking, the problem of maintaining a long life in such parts has to be tackled, first, by considering the production of a metal which is not hot-short; second, by production of a metal which will stand up to a chill or cast without the use of chills; third, by producing a metal in which the planes of graphite weakness are absent. The production of a material without planes of weakness leads the author to the conclusion that the line of development to take was to produce pearlitic cast irons.

The work given below was carried out some years before the publication of Diefenthaler's patent.

Analysis of typical fractured engine pistons gave:—(1) T.C., 2.93; G.C., 2.37; C.C., 0.56; Si., 1.3; S., 0.090; P., 0.78; and Mn., 0.61 per cent.,; and (2) T.C., 4.0; G.C., 3.3.; C.C., 0.7; Si., 1.26; S., 0.075; P., 0.75, and Mn., 0.80 per cent. Most of these failed by excess graphite and shrinkage.

In connection with steel it has long been understood that the highest tensile strength without undue brittleness can be obtained by means of structures which are pearlitic in character or are modifications of the pearlitic structures such as sorbite and troostite. For instance, in the manufacturing of wire which is specially drawn to give high tensile-strength, manufacturers have for many years carried out secret heat-treatment of the steel in order to give a pearlitic-sorbitic structure which, whilst in the early days it was not understood in theory, was fully understood in practice. As progress in the use of cast iron has been made engineers have always had in mind a cast iron which shall have the tensile properties of steel. The foundryman knows as a matter of practice such materials involve excessive difficulties in the foundry such as are only met with in the casting of steels. Many attempts have therefore been made to improve the tensile strength of cast iron and approach the properties of steel. Whilst one is approaching the properties of steel in the material one is at the same time losing the exceedingly useful properties of cast iron such as (1) low melting point; (2) fluidity when molten, and (3) expansion on solidifying, which make it a material capable of being easily cast in the foundry. One of the most important of these attempts was in the early days of last century when mixtures of steel and cast iron were manufactured under patents by Sterling in 1846. An attempt was then made to manufacture semi-steel by a partial refining of the iron. Later, in 1855, Nicholls and Price introduced a method of mixing refined iron and ordinary iron in the cupola, thus endeavouring to produce a stronger material. These two patents may be considered the basis of the material which is now known as semi-steel, and whilst the ideal semi-steel has not been attained in direct melting from the cupola the ideal to be aimed at in such a manufacture is a pearlitic cast iron.

The ordinary cast iron contains among its chief metallographic constituents the substance graphite, which is formed during the slow cooling of the iron; which lowers the melting point of the iron, and therefore enables it to be cast readily at low-temperatures in sand moulds without undue searching effect, and which also gives to the iron its readily machinable properties. On melting together pig-iron and steel under suitable conditions, the first noticeable item is the reduction in the graphite content and an increase in the strength of the material owing to the fact that the planes of weakness caused by the graphite are reduced. If the conditions are kept consistent the strength will increase directly with the proportion of steel added and the amount of graphite present. The addition of the steel, however, reduces the silicon-content so that unless means are taken to keep the silicon content high an iron with no machinable properties is gradually being approached, that is a hard iron. By proper adjustment of the silicon in the mixture it is easily possible to make a machinable iron using as much as 50 per cent. of steel. These materials, as ordinarily produced, however, are not pearlitic cast irons, although the pearlitic areas increase very considerably with increasing the silicon, and in general practice it is found that it is impossible to eliminate the graphite formed simply by addition of steel if machineability is to be main-

* A Paper read before the London Branch of the Institute of British Foundrymen, Mr. V. C. Faulkner presiding.

tained. If the silicon-content of the iron is kept high graphite absorption always occurs in the cupola, so that the resulting product appears more nearly related to an ordinary cast iron than it does to steel. Immediately the graphite is reduced by the addition of steel, difficulties are encountered owing to the quickness with which the metal will chill, and therefore it has been found in practice for semi-steels that 20 per cent. of steel is the amount which can be conveniently added for the purpose of manufacturing machineable castings without undue difficulty in adjusting the mixtures. Attempts have therefore been made upon different lines in order to produce pearlitic cast iron with a view to increasing the strength and at the same time avoiding any difficulties in casting. Two methods used are:—(1) To adjust the furnace running so that the graphite absorption is reduced to a minimum and the graphite-content of the metal kept below the limits required for excessive separation during the cooling, and (2) to manufacture a material in the cupola with a low graphite-content, subsequently annealing the casting so as to render it machineable.

In the second method, the castings are made from a mixture which contains low silicon, but which, at the same time, has sufficiently been superheated to change the hard white-iron into a pearlitic form. The annealing is carried on at a low temperature, and is done whilst the casting is

FIG. 3.—CRACKS ACROSS PISTON END.

still in the mould; the moulds are heated to a temperature as high as possible before the metal is poured, and the moulds, whilst the metal is still hot, are removed to an annealing oven so as to maintain the temperature for a considerable time whilst the hard iron is changed into pearlite. Annealing in an oven is not a very convenient process in the case of large castings, and since the metal is hard it does not have the advantages which ordinary cast iron possesses in expanding on cooling and so reducing the shrinkage which, as mentioned above, is one of the important features of cast iron from the foundry point of view. The cost of manufacture is also increased, and the object of this Paper is to indicate lines upon which the practical manufacture of pearlitic cast iron was attempted with a view to avoiding any annealing or other additional process than was ordinarily met with in the foundry.

In a Paper* previously published by the writer it was shown that cast irons of a certain type could be made whch would stand a temperature of 500 deg. C. for a period of 36 hours without any sign of breakdown. Iron of this class is very important for the manufacture of superheated turbine casings, Diesel-engine castings, and other internal-combustion engines. In recent years it has been the practice to manufacture superheated turbine casings from steel which involves considerable increase in cost. Superheated steam turbine casings will be subjected to a temperature of 300 deg. C. throughout the working period of their life,, and it has been shown that common cast iron, such as pipe lines, have given way at this temperature, and therefore engineers have been loth to make turbine casings from cast iron having these incidents in mind. Here again the wide variation in cast iron as a material of construction is realised. Cast iron is a term covering what should be considered to be a large number of materials. One cannot, for example, class together a No. 3 pig-iron casting and a high grade semi-steel casting, although to the mind of the average designer they would both be included in the term "cast iron." Such a metal would, undoubtedly, grow under low-temperature heat-treatment, and therefore one has to demonstrate to the users of these materials the fact that a large range of cast irons is possible, each one of which can be manufactured to suit definite requirements. The ideal pearlitic cast iron will be one in which the whole ground mass of the structure is pearlite and the composition of such a one may be as follows:—G.C., 2.75 to 2.5; GrC, 0.75 to 0.8; Si, 1.0 to 2.5; S, 0.05 to 0.13; P, 0.2 to 0.4; and Mn, 0.7 to 1.2 per cent.

In view of the low graphite and high combined carbon necessary, one is compelled to use low total-carbon irons in the mixture and also to make steel additions. A low phosphorus-content is also desirable.

It has been shown that sulphur was immaterial and could be balanced by suitable additions of manganese. While for low sulphur-content this is true, it is not a practical proposition to make castings of high-sulphur irons and balance the sulphur by manganese. Particularly is this the case with complex castings.

The high numbers of Scotch irons offer low phosphorus and low total carbon as a basis to commence work on pearlitic cast iron, and the writer used No. 7 of several well-known Scotch brands containing:—T.C., 2.83; GrC., 0.53; C.C., 2.30; Si, 0.91; S, 0.30; P, 0.4 to 0.7; and Mn, 0.3 per cent.

The charge was made up of 10½ cwt. pig; 4 cwt. steel; 45 lbs. ferro-silicon, and 3 cwt. scrap. The resulting metal gave an analysis of T.C., 3.6; G.C., 2.9; C.C., 0.7; Si, 1.4, S, 0.11; P, 0.13; and Mn, 0.94 per cent.

The material forged down under the hammer quite well from 2½ in. square down to ½ in. in thickness without fracture.

Other typical charges were:—8 cwt. No. 7 pig; 4 cwt. steel; 150 lbs. ferro-silicon, and 8 cwt. scrap. The analysis gave the following figures:—T.C., 3.55; G.C., 2.8; C.C., 0.75; Si, 2.6; S, 0.14; P, 0.34; and Mn, 0.8 per cent. The properties in this instance were not so satisfactory as in others.

A mixture which gave very good results was made up from the following charge:—10½ cwt. No. 7 pig; 4 cwt. steel; 100 lbs. ferro-silicon, and 5½ cwt. scrap. The analysis gave the following figures:—T.C., 3.2; GrC., 2.5; C.C., 0.70; Si, 2.76; S, 0.14; P, 0.39; and Mn, 0.6 per cent.

The tensile strength was over 18 tons, and the material readily forged without fracture. The elongation was 0.3 per cent., and the bend test on 12 in. by 1 in. by 1 in. bar took a permanent set of ¼ in. of arc at a load of 32 cwt. without fracture. To get the correct structure the necessary superheat for removal of any chilling effect is necessary, and with the correct mould-temperature it was easily possible to cast such metal on a 3½-in. chill without having subsequent difficulty in machining.

One interesting fact which came to light in this work was the lack of direct connection between Brinell hardness and combined carbon. Material with low-combined carbon gave Brinell-hardness figures higher than given by material with high-combined carbon.

The tensile strength of material of this class is of the order of 18 to 22 tons to the square inch, and can be compared with a good semi-steel running 14 to 16 tons per sq. in., and a good cast iron running 10-12 tons per sq. in. A material of this class can be manufactured directly in a reverberatory furnace. It can also be manufactured artificially in an electric furnace in both of which cases suitable superheat can be added to enable it to be cast without chilling. Castings, however, made in this way have to be subsequently annealed. The writer manufactured pearlitic cast iron directly in the cupola with the object of casting direct and also of avoiding any annealing process by method (1) above. It was found that the product obtained, whilst pearlitic in character, contained also temper carbon, small granules of graphite but less flake-graphite, and the whole question involved is one of control of the cupola. The iron, when cast, showed a very close-grained structure, and was entirely pearlitic with small particles of globular graphite spread amongst the

* See Foundry Trade Journal, November 15, 1923, page 421.

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ground mass. In each case the tensile strength taken on 2½-in. test pieces give 17 to 19 tons per sq. in. tensile strength.

Various complicated castings were run in this material and then broken up, but from several points of view were not satisfactory. The machineability was good; the tensile strength was good, but considerable blow-holes showed themselves in the intricate portions of the castings. The material did not require any annealing, but was cast in hot, dry loam-moulds. It showed, as anticipated, a fair tendency to chill, but when cast on 2½-in. chills of 2 ft. dia. was still machineable in the region of the chill on speeds usually found in heavy engineering practice. A comparison of this material may be made with centrifugal castings In the manufacture of centrifugal castings the material comes out in the hard, white condition, and a subsequent annealing is generally necessary. As the castings are practically chill castings they are very close-grained, and the graphite which is formed on annealing is in a fine flake form. Comparatively high silicon-contents are used, and the ground mass has a high tensile strength, up to 22 tons being quite a common figure. In order to soften the castings rapidly high-silicon mixtures are generally used, resulting in very rapid deposition of graphite and consequent deposition in flake form.

The production of pearlitic cast irons in practice depends upon:—

(1) Correct adjustment of mixture for ferrite, silicon, and graphite; a combined carbon in the region of 0.8 per cent.; (2) the use of low silicon suitably proportioned to the casting thicknesses and temperatures; and (3) quick cooling of the metal through critical ranges and subsequent continued low temperature annealing in the mould.

The writer is indebted to Mr. G. Walworth, M.A., for assistance in preparing the diagrams and slides.

Contracts Open.

Buenos Aires, June 12.—Pumping machinery, for the Argentine Sanitary Works of the Nation. The Department of Overseas Trade.

Dublin, June 2.—Steelwork for bridges, for the Midland Great Western Railway of Ireland Company. The Company's Chief Engineer, Broadstone Terminus, Dublin. (Fee, 8s.)

Gaiston, May 16.—Cast-iron pipes and special castings, for the Town Council. Elliott & Brown, Burton Buildings, Parliament Street, Nottingham. (Fee, £2 2s., returnable.)

Bangkok, July 1.—About 10,000 tons of steel rails and 580 tons of fishplates, for the Siamese State Railways. C. P. Sandberg & Company, 40, Grosvenor Gardens, London, S.W.

Darlington, May 19.—600 9-in. straight pipes, cast vertically in dry sand moulds, and delivered at Annfield Plain Railway Station, for the Durham County Water Board. Mr. H. Robinson, Bishop Auckland.

Liverpool, May 23.—(Schedule No. 1) Steel tramway rails and fishplates; (2) steel fishbolts; (3) steel tiebars; (4) copper bonds, for the City Council. The City Engineer, Municipal Buildings, Dale Street, Liverpool.

London, S.W., May 20.—300 steel axles for carriages and wagons (broad gauge), for the Madras & Southern Mahratta Railway Company, Limited, 25, Buckingham Palace Road, Westminster, London, S.W.1. (Fee. £1 1s., non-returnable.)

Grenoside, Sheffield, May 21.—Cast-iron pipes, special pipes, sluice valves, sludge valves, floating arms, handstops, screens, penstocks, bell syphons, and sundry steel angles, and for the supply and erection of 23 ft. diameter revolving sprinklers, in connection with the Wharncliffe Side sewage disposal works, for the Wortley R.D.C. Mr. F. Thurlby, engineer and surveyor, Council Offices, Grenoside, Sheffield. (Fee, £1 1s., returnable.)

Mr. Oliver Smalley, the well-known foundry metallurgist and consulting engineer, was recently married. His address in the future will be Park Villas, Thryberg, Rotherham.

The imports of foreign iron ore at the Senhouse dock at Maryport during April totalled 8,800 tons, against 10,400 tons for March and 4,000 tons at the corresponding period of last year.

Obituary.

Mr. W. H. Bairstow, iron and steel merchant, 19, Waterloo Street, Glasgow, died recently.

Mr. George Smith, crucible manufacturer, of 70, Langside Avenue, Langside, Glasgow, died recently.

Mr. G. Cully, metal broker, of Southend, was found dead in his office at 191, Bishopsgate, E.C., on May 2.

Mr. C. B. Wright, a director of the Hardware Supply Company (Middlesbrough), Limited, died recently.

Mr. J. K. Turner, who died on April 27, aged 88, was for many years connected with John Crowley & Company, Limited, ironfounders, of Sheffield.

Mr. A. H. Cooper, a former director of William Cooper & Goode, Limited, metal rollers and wire drawers, Bradford Street, Birmingham, died recently.

Mr. A. M. Forster, who for about 25 years was with the firm of G. E. T. Smithson & Company, metal merchants, Side, Newcastle, has died at the age of 45 years.

Mr. T. E. Driskell, who for many years was connected with Fawcett, Preston & Company, Limited, 77, York Street, Liverpool, manufacturing general engineers, died recently.

Mr. Alexander Hutchison, chairman of A. Hutchison & Son, Limited, bath manufacturers, London and Glasgow Foundry, Hancock Road, Bromley-by-Bow, London, E.3, died on April 26, aged 84.

Sir Alexander Wood, general manager in Scotland for W. & T. Avery, Limited, of Birmingham, died recently, aged 74. He was formerly a partner of Alexander Wood & Son, weighing machine manufacturers, which firm was eventually amalgamated with W. & T. Avery, Limited.

The death is announced of Mr. Albert Ladd Colby, a well-known American metallurgist. Mr. Colby is best known in this country for his work on standard steel specifications in the United States. He had contributed many papers to various technical societies and was a member of the Iron and Steel Institute, the American Society for Testing Materials, etc. Mr. Colby, who lived at Bethlehem, Pa., U.S.A., and who was a relative by marriage to the late Mr. John Fritz, had been in England since last winter in connection with some work on vanadium.

Gazette.

The Carrick Foundry, Limited, Bradford Road, Keighley, are being voluntarily wound up. Mr. J. R. Watson, 5-9, Old Bank Chambers, Bradford, is the liquidator.

The shareholders of the Clayton Valve Company, Limited, have decided that the company be wound up voluntarily. Mr. C. D. Harrison, 22, Birley Street, Blackpool, has been appointed liquidator.

Messrs. J. Hughes, B. L. Pidduck and J. E. Green, tool, file and tap and die manufacturers, Arpley Works, Warrington, trading under the style of Joseph Hughes, have dissolved partnership.

Mr. A. S. John, of 1, Vaughan Street, Llanelly, and The Links, Pembrey, whose statement of affairs showed gross liabilities of £48,343 and a deficiency of £45,317, came up for his public examination at the Carmarthenshire Bankruptcy Court. Debtor attributed his failure to losses on contracts, a slump in prices owing to depression in trade, bad debts, and the action of the Belgian Government in preventing the export of scrap material which he had purchased. Debtor said he had previously been a colliery manager, and his first venture was in 1914, when he began business at Vaughan Street, Llanelly, as a metal merchant. In 1917 his net profits amounted to £25,000, and in 1918 to £15,000. He embarked upon an enterprise in the same line of business in 1917, when a company was formed called the Welsh Metal Extracting Company, Limited, the capital being £75,000, of which debtor paid in £25,000 in cash. In September, 1920, he purchased 1,000 tons of steel scrap at Antwerp at a cost of £8,750, but about a month afterwards the Belgian Government put a ban on exports of scrap, with the result that he got nothing out of the transaction. The examination was adjourned.

At a meeting of the shareholders of the Britannia Iron & Steel Company (Bilston), Limited, held at the Alma Works, Walsall, the following resolution was passed:—"That it has been proved to the satisfaction of this meeting that the company cannot, by reason of its liabilities, continue its business and that it is advisable to wind up the same, and accordingly that the company be wound up voluntarily; and that Mr. F. W. Picken, 23, Colmore Row, Birmingham, be appointed liquidator."

Institute of British Foundrymen.

Discussion on Mr. Field's Paper on "Pig-Iron: Its Characteristics and Uses."

BIRMINGHAM BRANCH.

Before asking Mr. Field to read his Paper, the Branch President (Mr. J. B. Johnson) handed to him a diploma awarded to him by the Institute in recognition of the excellence of his Paper on Semi-Steel, read before the Birmingham Branch during the session 1920-21. There was no member of the Institute, the President said, who was held in higher respect than Mr. Field.

In accepting the diploma, Mr. Field said he esteemed it a great honour to be the recipient of such an award, especially in view of the valuable papers presented to the Branch by other members.

Vote of Thanks.

Proposing a vote of thanks to Mr. Field, Mr. Thomas Vickers congratulated him upon his able paper and the skilful way in which he had skirted around various difficulties. He was waiting to hear what Mr. Field had to say on the subject of Fracture *versus* Analysis, but he wisely left it alone. It was a paper which would be of great use to foundrymen generally. Mr. Field had called attention to the fact that the blast furnace production of each district had its own characteristics and that it was necessary for foundrymen to study those characteristics so far as they affected their own work. Even when foundrymen took the greatest care in purchasing pig suitable to their requirements, and adopted certain mixtures, the essence of the whole work was still the cupola melting process. A great deal of the blame thrown upon pig-iron was caused by faulty methods of producing castings from that pig-iron.

MR. A. MARKS also described the paper as one of the greatest utility to practical foundrymen. Mr. Field had given a very able review of the whole position with regard to the use of British pig-irons. He (the speaker) was still of opinion that the subject of mixtures could be quite adequately dealt with from the analytical point of view, and that when one knew one's cupola there was little difficulty in getting any desired mixture, even with rather diverse pig-irons. During the war many of them were forced to use at a moment's notice pig-irons which were quite unsuitable. When materials were scarce the job had to be done and it was done by working from analysis, conclusively proving that the only correct method of dealing with mixtures was to know what they required and then mix it in the cupola, assuming a fair knowledge of what was taking place in the cupola. The weakness generally in dealing with the various brands of pig-iron had been that they had not thoroughly understood the changes which were possible in the cupola. The cupola was most conveniently regarded as a blast furnace of a small type, and in melting iron, if they kept in view the changes which were there possible, they would find that they were able to work very accurately to analysis.

The motion was enthusiastically carried.

MR. PARSONS commented upon the difficulty from the practical foundryman's point of view of the wide range of selection in providing himself with suitable material for the castings he desired to make. He pointed out that in irons of almost similar analysis there appeared to be inherent differences, and that it was possible to get variations of chill in rolls cast from the same ladle. Reference had been made to low carbon, reducing it to 2.7 per cent. He had been making chilled rolls for fifteen years and he had never reached that figure in any mixture he had ever had. It seemed to him that with such a percentage of carbon, remelting in an air furnace was hardly admissible.

Replying upon the discussion, MR. FIELD expressed the opinion that unless some means such as a receiver or a double tap hole were used, if diverse irons were melted in a large cupola and drawn away in hand ladles, there was likely to be divergence. He was under the impression that people making automobile cylinders were careful to use suitable mixtures if the castings were made in quantity. Many people in the motor trade with whom he had conversed had emphasised how very strict the regulations were which guarded the analysis of the cylinders they made. His experience was that they had very good wearing properties with high silicon metal, but he believed that with the silicon lower and the manganese higher, generally speaking the wear was better. He did not think there was any difficulty in melting iron with 2.7 of carbon in an open hearth furnace. He knew a number of founders did it. That was about the lowest figure that one could get in the cupola, and he did not think they could get it very often if they were only using pig-iron, because the amount of pig-iron available with that carbon content was limited.

EAST MIDLANDS BRANCH.

MR. RUSSELL, opening the discussion, said a very fair exposition of the subject had been given without being dogmatic in any way, and that attitude was not perhaps so conducive to discussion. In many works there was no chemist, and he wondered how far one could rely on the analysis supplied by the various blast furnaces. If South Wales district did not produce foundry iron, where did they get it from?

As regards Northants iron, it was the cheapest pig locally. Was it cheapest because it was of less value from the foundryman's point of view, or were the furnaces more modern and could they produce more economically, and thus sell at a lower price? Did quality or method of production keep down prices?

With reference to Mr. Field's point as to phosphorus and the question of fluidity and expansion, many in that district were making light castings, and it might be of interest to members to know that phosphorus gave three different expansions while cooling, and they would see how that helped to keep sharp castings, and in ornamental castings a high-phosphorus iron was very helpful.

MR. FIELD said he believed it was the case that Northants ore was brought to Derbyshire. In South Wales, he understood, they used hematite made in the district, together with grey scrap of various grades for the general run of foundry work, whilst for the higher class work, such as rolls for the tin-plate mills, the iron was brought from the Midlands (*i.e.*, the South Staffs high-grade irons and cold blast), but if they paid for the import of iron they could, on the other hand, get coke ready at hand. He could not emphasise too strongly the disadvantage of mixing dissimilar irons. In making light castings they usually drew straight from the cupola by hand ladle, and he did not see how they could draw a uniform mixture in every ladle, but if in half-ton ladles the chances were very much better. He thought one reason for the low price of Northants iron was that the market for high phosphorus iron was limited, and it was a case of supply and demand.

MR. RUSSELL: The difference is 3s. cheaper.

MR. FIELD said, with regard to the effect of phosphorus, he maintained it had very little effect in tensile strength, but with regard to transverse strength, this was very sensitive to changes in phosphorus. Makers' analyses gave a rough indication and were a guide, especially in regard to manganese and phosphorus, but supplies varied. For silicon they had the fracture indication, and it was nothing unusual to get a 2 per cent. variation in silicon between the highest and the lowest deliveries on one contract.

MR. FIELD, answering a question, said foundrymen could not obtain maximum physical properties unless they had low total carbon. Distribution was even more important than size.

MR. STEVENSON proposed a vote of thanks to Mr. Field for his Paper.

MR. J. LUCAS seconded: and in reply to a remark by the former speaker, Mr. Field said he did not think an increase in manganese from 0.4 to 0.8 per cent should have an effect on the furnace lining. A low silicon iron had a sort of hunger for the lining and high steel mixtures also caused much damage in this respect.

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Trade Talk.

Mr. J. Booth has resigned his position as production engineer of Petters, Limited, Yeovil.

The Federation of Foundry Unions have decided to apply for an advance of £1 per week.

Moore Brothers (Birmingham), Limited, of 26, Tunnel Avenue, East Greenwich, London, S.E.10, have been granted a licence under the Non-Ferrous Metal Industry Act, 1918.

British Electric Vehicles, Limited, Churchtown Works, Southport, have removed their London office from 1, Queen Victoria Street, E.C.4, to 36/37, Old Jewry, London, E.C.2.

The Federated Associations of Scrap Iron, Steel, Metals and Machinery Merchants of Great Britain will hold their quarterly meeting at Charing Cross Hotel, London, W.C., on May 29.

The Whitlay Tool Company, 11, Queen Victoria Street, London, E.C.4, have been appointed representatives for the H. A. Dudgeon Machine Company, Lloyds Bank Chambers, High Street, Coventry.

Newton Brothers (Derby), Limited, Derby, have appointed Mr. J. F. Bradshaw, late works manager of J. Stirk & Sons, Halifax, a member of their staff in connection with the Newton Derby patent reversing drive.

Members of the West of Scotland Branch of the Association of Mining Electrical Engineers to the number of 174 visited the Shotts Works recently at the invitation of the Shotts Iron Company, Limited.

We understand that the question of amalgamation between the Electrical Trades Union and the National Amalgamated Union of Enginemen, Firemen, Mechanics, Motormen, and Electrical Workers is under consideration.

Of the fifty engines built at Woolwich Arsenal following the Armistice, twenty have just been disposed of by the George Cohen and Armstrong Disposal Corporation to the Southern Railway, where they will be put into commission at once.

The Paterson Hughes Engineering Company, Limited, 36, Charlotte Lane, Glasgow, have just completed the construction of new works on the most up-to-date lines, and in future their address will be the Wyndford Works, Lochburn Road, Maryhill, Glasgow.

In recognition of the long service to the firm of Hy. Rogers, Sons and Co., of Wolverhampton, Mr. J. E. Craddock and Mr. F. W. Craddock, who have been with the company respectively 52 and 50 years, were, recently, each presented by the company with a gold watch suitably inscribed.

The s.s. "Marvel," berthed at Tennant's Wharf, Swansea, recently, commenced unloading a cargo of pig-iron at 7 a.m., and by 4.30 p.m. on the same day had discharged 100 wagon-loads, whilst the s.s. "Glynwen," berthed at the West Wharf, discharged 95 wagon-loads in the same time.

Vickers, Limited have secured an order from the Furness Withy's Warren Line for a passenger cargo steamer for their Liverpool, Newfoundland and Canadian service for delivery next spring. The vessel will be deadweight over 7,000 tons, fitted with quadruple expansion engines speeding 14 knots.

The Council of the Institution of Civil Engineers announce that Professor Elihu Thomson, of Massachusetts, U.S.A., has accepted an invitation to deliver the thirtieth James Forrest Lecture during a visit to this country, and accordingly the lecture, which was originally fixed for May 6, has been postponed until Tuesday, July 8.

During their Majesties' visit to the British Empire Exhibition on May 2, the King inspected the various exhibits in the Palace of Engineering and started up the automatic sub-station on the British Thomson-Houston Company's stand. Their Majesties were able to see the illumination of this stand in its fullest splendour and expressed themselves delighted with the effect.

It is proposed to arrange a summer meeting of the members of the Institution of Locomotive Engineers at the Wembley Exhibition on Friday, June 20, to be extended to Saturday, June 21, if sufficient general desire is apparent. The programme so far proposed is a visit to the Palace of Engineering, followed by a reception and lunch (at the Exhibition) in the morning, and in the afternoon a visit to the Exhibition generally, followed by a tea.

The Industrial Court has issued its award in connection with a claim made by the National Joint Committee of Trades Unions in the railway wagon building and repairing trade, that workpeople employed on night-shift in the railway wagon department of the Butterley Company, Limited, at Codnor Park, Nottingham, should be paid the recognised allowances for the railway wagon building trades. The Committee, acting on behalf of about thirty men concerned, made an application on January 17 for the payment of night-shift allowances recognised in the industry. Negotiations ensued, but no settlement was reached, and it was agreed to refer the matter to the Industrial Court. After hearing the parties in London, on April 24, the Court has come to the conclusion that the Committee have established their contention that the settlement of the question of the night-shift allowance should not be made contingent upon the revision of the piece prices. The Court also decided that night-shift allowances at the rate of one quarter of the day rate (including war advances) should be paid to the men concerned on night-shift, the decision to operate on and from January 17.

Company News.

Glenfield & Kennedy, Limited.—Dividend, 5 per cent. for year.

Johnson & Phillips, Limited.—Net profit, £28,715; brought forward, £18,114; dividend, 5 per cent. on ordinary shares, less tax; carry forward, £24,954.

Midgley & Son, Limited, 4, Norfolk Row, Sheffield.—Capital £5,000 in £1 shares. Steel merchants. Directors: S. R. Midgley, E. L. Midgley, and Jane E. Midgley.

Robert Stephenson & Company, Limited.—Loss, £22,024; brought forward, £79,514; credit balance, £57,491; dividend, 4 per cent. for year, less tax: carried forward, £49,034.

Ropers (Birmingham), Limited, 345, Bellbarn Road, Edgbaston, Birmingham.—Capital £3,000. Architectural engineers and general brass founders, etc. Directors: C. S. Smith and F. Roper.

Frank Pickering & Company, Limited, 20, Bedford Street, Sheffield.—Capital £100 in £1 shares. Iron, steel and metal manufacturers and merchants. Directors: F. Pickering and B. Burkinshaw.

Brunner, Mond & Company, Limited.—Dividend on ordinary, 14 per cent. p.a., making 10½ per cent. for year, less tax; £150,000 placed to suspense account, £88,000 general reserve, and £86,000 carried forward.

English Crown Spelter Company, Limited.—Credit balance, £2,331; brought forward, £2,289; £5,000 transferred from equalisation of dividend reserve account; dividend, 2s. per share, less tax, £7,687; carried forward, £1,932.

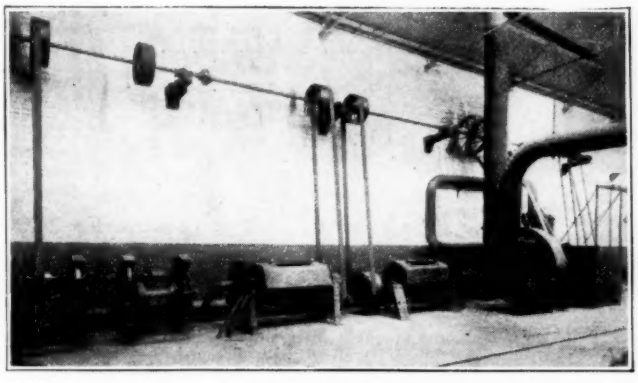
E. Calderbank & Sons, Limited.—Capital £6,000, to take over the business of a machinery and metal merchant carried on at Orchard Street and Britannia Bridge, Wigan. Permanent governing director and chairman: E. Calderbank.

William Dixon, Limited.—Profit, £56,656; brought forward, £15,497; interim dividend on 5 per cent. cumulative preference shares, £7,500; redemption of debenture stock, £15,000; dividend on 5 per cent. cumulative preference shares, £7,500; dividend, 5 per cent. on ordinary shares, less tax, £32,800; carried forward, £9,354.

Pease & Partners, Limited.—Profit, £341,631; surplus provision made for excess profits duty, £200,000; brought forward, £122,147; interest on debenture stock, etc., £66,195; writing off discount on 5 per cent. debenture stock issued in December, 1922, £112,500; interim dividend, 3 per cent. (free of tax) on ordinary shares, £66,155; special expenditure, £59,327; depreciation reserve, £75,000; reserve for liability under the Workmen's Compensation Act, £50,000; dividend, 5 per cent (free of tax), making 8 per cent. for year, £110,192; carry forward, £124,927.

English Electric Company, Limited.—The fifth annual meeting has been held in London, Sir Charles E. Ellis presiding. The chairman, in moving the adoption of the report, stated that the orders received during the year under review were much in excess of those for the previous year, and contracts were obtained from all parts of the world. Their satisfactory progress in water-power development had been more than maintained. Over 200,000 h.p. of water turbines with the appropriate generating plant were sold during the year, and they secured orders for the largest units ever manufactured in this country, both for high and low falls. "English Electric" motors and control equipment were thoroughly established on the Midi Railway of France. A very large order for electric locomotives for the Japanese Government Railways was delivered partly before and partly after the earthquake, and it was a tribute to their many friends in Japan that in spite of the appalling disaster which overtook that country the majority of the locomotives were installed and ready for operation. Work on the equipments for the electrification of the Great Indian Peninsular Railway was well on towards completion. Their largest traction contract for the year at home was for the electrification of the South-Eastern section of the Southern Railway; that order comprised 508 motors each of 300 h.p. and nineteen 1,500 kw. rotary converters. The whole of the active productive units of the company were working full time, and this happy state of affairs was likely to continue for some time.

GRINDING OF METALS



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IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—The easier conditions in the Cleveland iron market noted in previous reports continue in evidence, and although makers' order-books are comparatively well filled new contracts are by no means circulating as freely as could be desired. There can, however, be no doubt that many of the foundries are short of work, and consumers consequently are holding off buying until the outlook improves. In the export trade business is fairly well diffused, but there is no great tonnage involved, and here again there is a substantial quantity of iron still awaiting despatch. At present Tees-side makers have probably sold as much as three times the amount of stock on hand, and the bulk of this represents not speculative but legitimate purchases. Moreover, Cleveland iron is the cheapest in the country, and although fuel values are easier a reaction may set in at any time. No. 3 G.M.B. is quoted at 92s., but could be done at 91s. 6d. for fair quantities. No. 1 is about 97s. 6d., No. 4 foundry in the region of 91s., and No. 4 forge about 90s. per ton.

The Tees-side hematite market is certainly steadier. In the home trade there is a little more buying from Sheffield, and from the Continent a fairly steady inquiry continues. Here and there it is still possible to buy at 98s. 6d., but on the other hand as much as 100s. is asked in some quarters, and the average quotation remains at 99s. per ton for East Coast mixed numbers. The No. 1 quality is at a premium of 1s. per ton. In West Cumberland and North Lancashire hematite prices are firm, with Bessemer mixed numbers at £5 8s. 6d. per ton, delivered at Glasgow, £5 12s. 6d. Sheffield, and £5 17s. 6d. per ton at Birmingham. Low-phosphorus iron is in fair request by steelmakers in the Sheffield district.

MANCHESTER.—Business in the local iron markets continues on a moderate scale, most consumers having previously bought fairly well before the holidays, under the impression that a rise in Cleveland prices was imminent, and consequently demand is now restricted. At present nearly all kinds of Midland pig can be bought in Manchester, carriage paid, at 102s. 6d. per ton. For Lincolnshire No. 3 foundry there is a small market here at 103s. 6d. to 104s. delivered, but the reason of the higher price is that the quantity now being produced is very limited.

THE MIDLANDS.—In the Birmingham market last week the amount of business passing was much below earlier expectations. Prices of Derbyshire and Staffs. foundry iron remain unaltered at 95s. f.o.t., but the Northants. makers are quoting irregularly, some of the furnaces accepting below 92s. 6d. per ton f.o.t., which has been the ruling price for a considerable time. There is no Continental foundry iron being brought into the district. South Staffs. No. 3 iron at 99s. is about the cheapest iron in this locality; it works out about 1s. 6d. to 2s. per ton under the Northants. price. The current prices are as indicated below:—Derbyshire No. 3 foundry, 95s.; Staffordshire No. 3 foundry, 95s.; Northants. No. 3 foundry, 92s. 6d.

SCOTLAND.—Very little improvement can be noted in the position of the Scottish pig-iron markets, but so far there is no change in price, No. 3 foundry remaining nominally at 100s. f.o.t. furnaces. No. 3 Middlesbrough is now quoted by the makers at 98s. f.o.t. Falkirk, with No. 4 foundry at 2s. per ton less. No. 4 foundry iron seems to be rather scarce, but at the same time there is sufficient to meet buyers' needs.

Finished Iron.

The position in the manufacturing branches of the industry, apart from the mills making marked bars and best irons, is not at all satisfactory, and is causing considerable anxiety. There are so few forges at work now, and these are anything but overburdened with specifications. The makers of crown iron are doing their utmost to get £13 per ton delivered, but the competition is too keen to get this price for any substantial tonnage. Marked bars remain at £15 f.o.t. makers' works, and there is still a fair demand for this iron and for tested iron for the wagon trade. There is little movement at present in the demand for nut and bolt iron, while the Continental merchants are again quoting £8 15s. to £9 for forward delivery.

Steel.

There are no fresh developments to report in the various branches of the industry, and although makers of basic and acid billets are doing rather better business it is on nothing like the scale which promised at the beginning of the year. Soft basic billets hold at £8 5s., medium at £10, and hard at £10 5s. Siemens' acid are £12 10s. No further improvement can be noted in ferro-manganese, both the home and export demand being on very small lines. Similar conditions prevail in the United States, where the price of both the imported and domestic article is $107.50 (£24 10s.) duty paid tidewater. Quiet conditions continue to prevail in the tinplate market, and in some quarters there are hopes of lower quotations. Prices range round 24s. 1½d. basis I.C. f.o.b. works' port, though second-hand parcels have been down to 23s. 9d. basis I.C. f.o.b. for July-August shipment.

Scrap.

Markets for scrap metal are, with few exceptions, lifeless as regards actual business, and in some districts dealers have larger stocks in hand than are usual at this time of the year. The threatened strike of foundry operatives will by no means tend to improve the existing conditions in the scrap trade, and the demand for cast scrap material is very poor. In Lancashire, even at 87s. 6d. per ton, there is no adequate demand for broken machinery iron, although common pig-iron is still at 102s. 6d. At Sheffield, if anything, there is a slight improvement in the call for heavy steel scrap at 87s. 6d. per ton, delivered Sheffield, merchants holding for 90s. at least. In Scotland, heavy machinery cast-iron scrap is still slow to move, as foundries are not buying much.

Metals.

Copper.—Although a fair volume of business is transacted daily in the standard market, conditions all round may be best described as below average activity. Demand for home consumption continues on a moderate scale, while business with Continental buyers is naturally restricted by political and financial difficulties. Operators at home and abroad are becoming rather nervous about the outcome of the settlement of the May account on the leading metal exchanges, and although the heavy losses suffered recently were mainly in connection with speculative dealings, business in copper is necessarily affected sympathetically. Current quotations.—*Cash*: Thursday, £62 17s. 6d.; Friday, £62 12s. 6d.; Monday, £62 5s.; Tuesday, £61 12s. 6d.; Wednesday, £61 17s. 6d. *Three Months*: Thursday, £63 15s.; Friday, £63 10s.; Monday, £63 2s. 6d.; Tuesday, £62 15s.; Wednesday, £62 10s.

Tin.—Movements in standard tin during the past week have been irregular and inclined to further weakening of values, notwithstanding the fairly satisfactory conditions of the statistical position for April, showing a decrease in the total visible supplies. Demand for tin from America is reported to have been fairly good of late, so that the threatened slowing-down of industry has so far not been translated into lessened purchases on this market; but owing to the quieter condition at the South Welsh tinplate mills, home inquiry has been rather dull.

Ricard & Freiwald's statistics of tin for April are appended:—

Stocks, Landing and Afloat, Europe and America.—United Kingdom: Stocks in London, 1,583 tons; stocks in other ports, 2,536 tons; total, 4,124 tons. Landing and in transit, 280 tons; afloat from Straits, 2,025; afloat from Australia, 195; total United Kingdom, 6,624 tons. Holland: Banca spot, 1,450 tons; Banca and/or Billiton afloat to Europe and America, 517 tons. Continent: Straits afloat, 580 tons. United States: Spot and landing, 4,322 tons; afloat, 2,800 tons. Total visible supply, 16,293 tons

Current quotations:—*Cash*: Thursday, £224; Friday, £227 15s.; Monday, £229 15s.; Tuesday, £225; Wednesday, £225 5s. *Three Months*: Thursday, £224; Friday, £227 10s.; Monday, £229 10s.; Tuesday, £224 5s.; Wednesday, £224 15s.

Spelter.—Transactions in this metal disclose a further drooping tendency, and the market continues decidedly weak. Rudolf Wolff & Company state that this further set-back must, in a measure, be attributed to constant liquidations. In the U.S.A. prices tended to follow the course of the London market, and it would seem likely that the present low level of values will occasion some regulation on output. Published figures give stocks on May 1 at 673 tons, a decrease of 185 tons. Current quotations:—*Ordinary*: Thursday, £29 15s.; Friday, £30 8s. 9d.; Monday, £30 13s. 9d.; Tuesday, £31 5s.; Wednesday, £31 5s.

Lead.—The market for soft foreign pig continues unsettled, and although the technical position is practically unchanged values have developed a lower tendency. Current quotations:—*Soft foreign (prompt)*: Thursday, £27 15s.; Friday, £28 15s.; Monday, £29 10s.; Tuesday, £29 5s.; Wednesday, £29 7s. 6d.